

## **Chapter 3 - Alternative High-Voltage Transmission System Improvements in Wisconsin**

### **Transmission System Alternatives to the Arrowhead-Weston Line**

Several alternative transmission lines, connecting different parts of the existing transmission system, could provide transmission system benefits comparable to those of the proposed line.<sup>47</sup> This chapter examines several such alternatives and assesses both the benefits they might provide to the power system and the risk of environmental impacts associated with each. The engineering analysis is presented first; the environmental analysis follows. In addition to discussing several overhead, alternating-current (AC) transmission alternatives, a brief introduction to high-voltage direct current (HVDC) and underground transmission technologies is presented. This chapter does not consider transmission projects that are significantly less effective in improving import capability than the proposed project, nor does it discuss other means of alleviating the need for system improvements, such as increased generation. These topics are the focus of Chapter 4.

The analysis in this chapter examines various aspects of the transmission alternatives to the proposed line, one at a time. In some cases, the analysis and discussion bearing on a single alternative or factor may arrive at a particular observation. These singular observations should not be taken out of context. The complexity, size and scope of the Arrowhead-Weston Transmission Project require a balanced consideration of the proposed project and all of its alternatives.

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<sup>47</sup> The reader should distinguish these “system” alternatives, which are lines between different endpoints, from the various “route” alternatives for the proposed Arrowhead to Weston line that are discussed in Chapters 6-9. Each route alternative commences at the Arrowhead Substation and ends at the Weston Substation.

# Engineering Analysis of Transmission System Alternatives

## WIRE study

The Wisconsin utilities carried out a study in 1998 and 1999 that examined the power system benefits of several new transmission line possibilities. Commission staff participated in the first phase of this study, which was used as the technical basis of the PSCW's September 1998 Report to the Wisconsin Legislature on the Regional Electric Transmission System. Commission staff had an observer role in the second, final phase of the study. This study is known as the WIRE study. The WIRE study included a wide range of engineering assessments that were based on power system models reflecting expected summer 2002 conditions.

In its initial phase, the WIRE study examined more than a dozen alternative lines and several dozen project variations based on these lines. Under the direction of the WRAO, the WIRE study participants decided that only those variations that demonstrated the potential to permit import of 3,000 MW into eastern Wisconsin should be carried into the second phase of the study.

The reader may note that this target import capability is about 2,000 MW more than today's import capability of roughly 1,000 MW, and that this is a larger increment than the power carrying capacity of the proposed line. It is possible for a new transmission line to increase inter-regional transfer capability by more than its own rating, by altering the flow on other lines so as to alleviate limits.

The list of possible projects developed in the first phase of the WIRE study was further refined to eliminate redundancy while retaining a range of alternatives, yielding the seven lines listed in Figure 3-1. For consistency, the transmission line projects that appear in this chapter are presented in the same order adopted in both the WIRE study and the application, and the same two-character designations are used.

**Table 3-1 Transmission alternatives analyzed in WIRE study**

Designation	Western Terminus	Eastern Terminus	Voltage
1c	Salem (IA)	Fitchburg <sup>48</sup> (WI)	345 kV
2e	Prairie Island (MN)	Columbia (WI)	345 kV
3j	Arrowhead (MN)	Weston (WI)	345 kV
5a	Chisago (MN)	Weston (WI)	345 kV
5b	Chisago (MN)	Weston (WI)	230 kV
9b	Lakefield Jct. (MN)	Columbia (WI)	345 kV
10	King (MN)	Weston (WI)	345 kV

<sup>48</sup> This alternative also includes a Rockdale-Fitchburg-North Madison 345 kV line.

The power system models used in the WIRE study assumed that a number of relatively minor transmission improvement projects – much smaller than the major new interconnections shown in Figure 3-1 – would be installed by summer 2002. Most of these projects are small, involving modifications within substations or improvement of existing lines, and requiring no regulatory approval. One notable exception is the Chisago-Apple River 230 kV transmission line, which would provide a connection between Minnesota and Wisconsin near St. Croix Falls.<sup>49</sup> This transmission line received approval from the PSCW, but was still awaiting a decision from Minnesota regulators when it became the subject of lawsuits brought by project opponents. A settlement has since been negotiated in which the Chisago applicants would abandon their plans to build a 230 kV line, and instead would build a 161 kV line between the Chisago and Apple River substations. One party that filed a lawsuit, however, has not accepted this settlement. Thus the question of whether and at what voltage this line will be built remains unresolved. The effect of changes to the 230 kV line assumed in the WIRE models is discussed following the presentation and discussion of the WIRE study results.

In addition, a number of projects, mostly upgrades of existing transmission lines and changes in substation equipment, were found to be necessary during the course of the WIRE study in order to achieve the transfer levels reported in the study results. A number of issues surrounding these additional facilities are discussed after the main discussion of the WIRE study and the presentation of results.

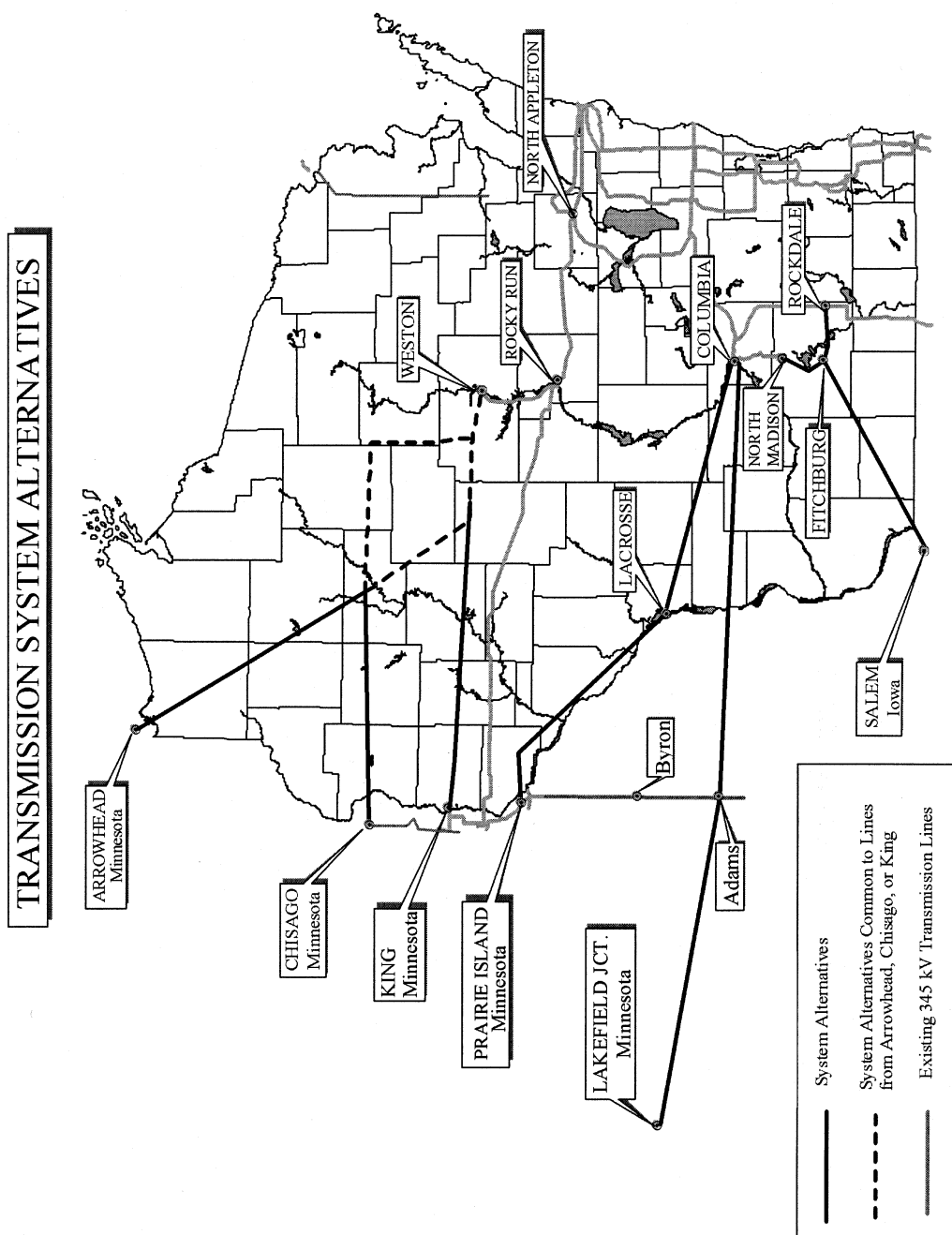
As discussed in Chapter 2, the need to import power into eastern Wisconsin may be significantly less than 3,000 MW, depending on the amount of new generation that is built. Accordingly, while the set of lines shown in Figure 3-1 is a good representation of the lines that could provide performance comparable to the proposed line, it probably does not include all reasonable alternatives if this 3,000 MW threshold were significantly reduced.

The WIRE study attempted to accomplish a great deal of analysis in a relatively short time. To facilitate this process, different models were used for different parts of the study. These models employed somewhat different assumptions regarding the pattern of generation across the region. As a consequence, the analytical results for different parts of the study are not always directly comparable. Within each part of the study, however, it is possible to directly compare the relative performance of the proposed line and the alternatives considered.

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<sup>49</sup> The transmission line alternatives that begin at Chisago (Chisago-Weston 345 kV and Chisago-Weston 230 kV) would supersede the Chisago-Apple River 230 kV line. The Chisago-Apple River construction case consists of dockets 4220-CE-155 and 1515-CE-102.

Figure 3-1 Transmission line system alternatives to the proposed Arrowhead-Weston Line



Heavy solid and dashed lines represent 345 kV lines, except that a 230 kV line between Chisago and Weston, which could follow either dashed route, was also considered.

Although it has some shortcomings, as outlined above, the WIRE study remains the best source of information on the question of performance of the proposed line and its system alternatives.<sup>50</sup> Accordingly, this study provides the basis for most of the quantitative engineering results discussed in this chapter.

## Engineering analysis results

From an engineering perspective, the benefit of a transmission line is a function of its ability to support the transfer of power across the system. Several types of limits may restrict the ability of the transmission system to transfer power. Tables 3-2 through 3-5 present the results of several different engineering analyses that describe the effect of the various transmission line alternatives on each type of limit. Cost estimates are also presented. The following sections describe each of the categories of engineering results that appear in these tables, and should be helpful in their interpretation.

### Thermal limits

Table 3-2 describes the effect of each transmission alternative on thermal limits. Thermal limits arise from the fact that, as power and current flows increase, power lines and equipment in various locations can overheat. Thus, flows must be restricted to avoid equipment damage. In some cases, the limiting factor is not equipment damage but excessive sagging of current-carrying wires – known as conductors – at high temperatures. Minimum clearances of overhead conductors are established by law<sup>51</sup> in order to provide for public safety.

The thermal limits reported in Table 3-2 apply to single-contingency conditions. That is, they consider not only the case in which all transmission lines are in service, but also the more demanding case in which any one line or transformer unit is out of service.

The four rows of Table 3-2 correspond to four sets of assumptions about the location of generation and electricity demand in the power system and, in particular, the source of the power imported into Wisconsin. This range of input assumptions gives a more complete picture of thermal limitations than could be obtained from a single case. The values in each row refer to the maximum power that could be imported into eastern Wisconsin, from the indicated direction, without encountering a significant transfer limitation.

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<sup>50</sup> The complete study is available at <http://www.maininc.org/committees/wire~1.htm>.

<sup>51</sup> Wis. Admin. Code, chapter PSC 114.

**Table 3-2 Thermal limits associated with imports into the WUMS region, for each transmission alternative**

Transmission Alternative Analysis Thermal Limits	1c	2c	3j	5a	5b	9b	10
	Salem-Fitchburg 345 kV	Prairie Island-Columbia 345 kV	Arrowhead-Weston 345 kV	Chisago-Weston 345 kV	Chisago-Weston 230 kV	Lakefield Jct-Columbia 345 kV	King-Weston 345 kV
Southern imports into WUMS (MW) (with 1000 MW western imports)	2450	2370	2130	2150	2010	2400	2140
Western imports into WUMS (MW) (with 1000 MW southern imports)	2210	2580	2280	2270	2120	2750	2300
Western imports into WUMS (MW) (with 1000 MW southern imports) Source sensitivity	2110	2550	2190	2190	2140	2810	2200
Western imports into WUMS (MW) (with 1000 MW southern imports) Sink sensitivity	2160	2720	1860	1880	2160	2590	1890

Larger numbers indicate superior electrical performance.

The results in the first row, labeled “Southern Imports into WUMS,” indicate the amount of power that could be imported into eastern Wisconsin from states to the south and east of Wisconsin, while simultaneously importing 1,000 MW of power from states to the west. Thus the total import in each case is the sum of the value that appears in the table and 1,000 MW. Similarly, the results reported in the following three rows indicate the amount of power that could be imported from the west, while simultaneously importing 1,000 MW from states to the south and east. These three rows reflect three slightly different sets of assumptions about the pattern of demand and generation in the region.

### **Additional performance considerations**

Thermal limitations can readily arise with power transfers into Wisconsin from any direction. For this reason, Table 3-2 considers cases with imports predominantly from the south as well as in cases with imports predominantly from the west. In contrast, the characteristics shown in Table 3-3 describe potential limits that are of greater concern with power transfer from the west than from the south. This is largely a consequence of greater distances between generators and sparseness of lines in the system to the west. Accordingly, each type of limit was analyzed in cases of high power flows that are predominantly from the west.

**Table 3-3 Dynamic stability, voltage stability and Arpin-phase-angle impact of transmission alternatives**

Transmission Alternative Analysis Additional Performance Considerations	1c	2c	3j	5a	5b	9b	10
	Salem-Fitchburg 345 kV	Prairie Island-Columbia 345 kV	Arrowhead-Weston 345 kV	Chisago-Weston 345 kV	Chisago-Weston 230 kV	Lakefield Jct-Columbia 345 kV	King-Weston 345 kV
Dynamic stability – western transfer level (MW)	2050	2720	2450	2670	2220	2120	2480
Voltage stability – Western transfer level (MW)	2615	3245	2615	2865	2865	3105	2865
Western 3 impact – with 2000 MW transfer from west – improvement relative to existing reclose limit (per unit power on 100 MVA base)	-0.013	0.015	0.036	0.166	0.064	0.009	0.247

Larger numbers indicate superior electrical performance.

#### Dynamic stability

Dynamic stability is primarily concerned with the ability of the power system's rotating generators to return to a stable state after disturbances. When subjected to a disturbance during high power transfer conditions, power systems may exhibit oscillatory behavior, in which power transfer between different parts of the system fluctuates (on a time scale of a few seconds), and generators in different parts of the system alternately speed up and slow down. This may be accompanied by significant changes in the frequency or voltage of power supplied to electricity customers.

This is a potentially unstable condition, and it is an objective of system planning and operation to achieve damping of disturbances as rapidly as possible. (Damping is the elimination of such oscillations, just as shock absorbers damp mechanical oscillations in a car.) Damping performance tends to deteriorate as the level of power transfer through the system increases. Accordingly, power transfer must sometimes be limited to ensure adequate damping of system disturbances. Dynamic stability considerations are reflected in the first row of Table 3-3, in the form of transfer levels achievable at a specified level of system damping performance. These transfer levels indicate the amount of power that could be transferred into Wisconsin from the west; some imports from the south are also assumed in these cases.

#### Voltage considerations

Under certain high-transfer or line-outage conditions the power system may experience low voltages. This may result in the inability to provide adequate voltages to customers. An even greater concern is the threat of voltage instability or collapse, in which voltages may fall uncontrollably, leading to localized or widespread customer outages.

Table 3-2 incorporates voltage considerations as well as thermal considerations. Specifically, the import values in that table were tested to ensure that neither thermal nor voltage limits would be violated. An additional, more sophisticated voltage stability analysis was conducted within the WIRE study to further assess the relative performance of the alternatives. The results of this

analysis appear in Table 3-3. Unlike most of the other power system models used in the WIRE study, which assumed power imports into Wisconsin from the west and south, the model used for this analysis assumed a net flow of power from Minnesota into Wisconsin and from Wisconsin to the south. The analysis calculated the maximum transfer of power out of Minnesota that could be accomplished without risk of voltage instability. This analysis yielded voltage stability results that were not directly comparable to the thermal and dynamic stability limits calculated in the WIRE study. The voltage stability limits that appear in Table 3-3 reflect conversion of the original study results into terms that can be compared to the thermal limits in Table 3-2 and, approximately, to the dynamic stability limits in Table 3-3.

#### **Arpin phase angle analysis**

The Arpin phase angle problem is described in Chapter 2. The degree to which each transmission alternative could alleviate this problem is expressed in terms of the impact on power flow at the Weston 3 generator. The values in Table 3-3 describe this impact – the change in instantaneous power that would be experienced at this generator upon trip and reclose of the Eau Claire-Arpin transmission line – at a time when eastern Wisconsin is importing 2,000 MW from the west and 1,000 MW from the south.

The values in the table indicate the degree to which the adverse impact to the Weston 3 generator would be reduced relative to the existing transmission line reclose criterion. In other words, positive values in this table indicate that there should be no need to redispatch generation prior to returning the Eau Claire-Arpin transmission line to service, even under the high power transfer conditions that were assumed. The larger the value in the table, the smaller the disturbance that would result from reclosing this line and the more certain that the line could be immediately reclosed under a wide range of conditions.

Transmission line alternative 1c (Salem-Fitchburg 345 kV) is notable in that it is associated with a negative value. This performance falls short of the standard set in the WIRE study. Specifically, this result indicates that, at high transfer levels, reclosing the Eau Claire-Arpin line would have to wait for some adjustment of regional generation levels to take place. This is true in today's system at lower transfer levels, of course, and should not obscure the fact that a Salem-Fitchburg line would diminish the Arpin phase angle problem relative to today's system. Some additional transmission system projects might yield further improvements.

#### **Impact on regional power flows**

Table 3-4 presents additional results concerning the impact of the transmission line alternatives on power flows throughout the MAPP region. In order to appreciate these results, it is helpful to understand the nature of power flow behavior on the interconnected power system.

In North America, most of the area from the Great Plains east to the Atlantic coast forms a single interconnected power system. Changes in generation, electricity demand, or status of power lines in one area can affect flows hundreds of miles away. These effects are sometimes significant enough that power transfers in one area must be restricted so as to prevent the possibility of operating limit violations in another part of the system.

In fact, power transfers into Wisconsin (and elsewhere within the region) have been curtailed in the past because they would tend to increase power flows in distant parts of the system that were already near operating limits. To the extent that a new line tends to reduce the loading on those facilities that often experience heavy power flows, it would facilitate power transfers over a broad area.

**Table 3-4 Impact of transmission alternatives on loading of significant flowgates in the MAPP-MAIN region**

Transmission Alternative Analysis Impact on Regional Flowgate Loading	1c Salem- Fitchburg 3 45 kV	2c Prairie Island- Columbia 345 kV	3j Arrowhead- Weston 345 kV	5a Chisago- Weston 345 kV	5b Chisago- Weston 230 kV	9b Lakefield Jct- Columbia 345 kV	10 King- Weston 345 kV
MAPP OPPD flowgate	-1.2%	-9.3%	-7.9%	-8.6%	-5.5%	-12.4%	-7.9%
MAPP COOPER_S flowgate	-7.9%	-18.1%	-14.7%	-16.1%	-11.6%	-22.3%	-15.4%
MAPP ECL-ARP flowgate	-0.8%	-6.3%	-19.7%	-24.3%	-10.6%	-7.5%	-20.2%
MAPP PRI-BYR flowgate	1.3%	-26.1%	-15.5%	-18.3%	-9.0%	7.0%	-16.5%
MAPP MNEX flowgate	0.3%	-17.6%	-17.0%	-20.6%	-6.7%	8.1%	-20.2%

In general, larger negative numbers indicate superior electrical performance.

To aid in management of these problems, operators monitor several “flowgates.” A flowgate is typically a single transmission line; it may also be a collection of transmission lines that tend to be impacted similarly by a given pattern of power flow. The lines in the table labeled “OPPD Flowgate” and “COOPER\_S Flowgate” refer to lines in Nebraska and Missouri that are, at times, impacted by transfers into Wisconsin.<sup>52</sup> The values reported in the table are the percent changes in power flow, on the flowgate in question, that would result if a new transmission line were put into service.<sup>53</sup> The more negative the value in the table, the more significant is the beneficial reduction in flow that these facilities would be likely to experience.

The interpretation of the next three lines in the table (corresponding to flowgates designated ECL-ARP, PRI-BYN and MNEX) is less straightforward. These flowgate designations refer to transmission lines in Minnesota and western Wisconsin that are important in bringing power into Wisconsin.<sup>54</sup> As in the previous cases, large negative values mean that the new line would provide a significant alternate path to these facilities. Positive values indicate that the new line would tend to draw more power through these existing facilities, increasing flows. In either case, however, the limit associated with each flowgate would probably be recalculated if a new line

<sup>52</sup> The “OPPD flowgate” in this table is not a MAPP flowgate, but rather a composite of two actual MAPP flowgates in the Omaha Public Power District transmission area. “COOPER\_S” refers to the sum of power flows on the two 345 kV lines leading southeast from the Cooper power plant in southeastern Nebraska.

<sup>53</sup> This calculation assumes a particular pattern of power flow, corresponding to heavy transfers of power into Wisconsin from the west.

<sup>54</sup> “ECL-ARP” is the Eau Claire-Arpin line, “PRI-BYR” is the Prairie Island-Byron line and “MNEX” stands for Minnesota Export and refers to the sum of flows on six separate lines leading out of the Twin Cities area toward Wisconsin and Iowa.

were added across western Wisconsin. This means that the true impact of a new facility on the limit associated with these flowgates is not clear from this study. Nonetheless, these results give some indication of the degree to which each alternative would divert flows from existing lines.

### Costs

Table 3-5 presents the cost estimates developed as part of the WIRE study. These estimates were calculated by a different group than the cost estimates included in the application for the proposed transmission line, and the two estimates were based on somewhat different assumptions. As a result, the applicants' cost estimate for the proposed project differs from the cost estimate for the Arrowhead-Weston Transmission Project that appears in Table 3-5. Nonetheless, the cost estimates in the table should be useful in assessing the relative costs of the proposed transmission line and possible alternatives.

**Table 3-5 Economic comparison of transmission alternatives**

<b>Transmission Alternative Analysis Economic factors (all values in millions)</b>	<b>1c</b> Salem- Fitchburg 345 kV	<b>2c</b> Prairie Island- Columbia 345 kV	<b>3j</b> Arrowhead- Weston 345 kV	<b>5a</b> Chisago- Weston 345 kV	<b>5b</b> Chisago- Weston 230 kV	<b>9b</b> Lakefield Jct- Columbia 345 kV	<b>10</b> King- Weston 345 kV
Construction cost (all single circuit)	\$116-\$145	\$169-\$176	\$177-\$210	\$172-\$205	\$118-\$144	\$227	\$136-\$139
Construction cost (maximum feasible double circuit)	\$158-\$227	\$243-\$265	\$266-\$310	\$240-\$284	\$171-\$208	\$395	\$210-\$262
Relative cost of losses	\$50	\$27	\$0	\$1	\$39	\$29	\$21
Cost impact from avoided projects	\$0	-\$1 (-\$11)	\$0 (-\$11)	-\$47 (-\$8)	\$0 (-\$11)	\$0	\$0
Overall cost impact (all single circuit)	\$166-\$195	\$195-\$202	\$177-\$199	\$126-\$149	\$157-\$173	\$256	\$157-\$160
Overall cost impact (maximum feasible double circuit)	\$208-\$277	\$269-\$291	\$266-\$299	\$194-\$228	\$210-\$237	\$424	\$231-\$283

Positive values indicate cost and negative values indicate savings. Cost values in parenthesis apply only to particular routes.

Table 3-5 shows the range of costs among possible routes, as evaluated in the WIRE study. In addition, cost estimates were calculated under two distinct assumptions regarding the design of the new line. The "All Single Circuit" estimates assume that the new line would be supported entirely on new structures that would hold only the new line. In contrast, the "Maximum Feasible Double Circuit" cost estimates assume that the line would be double circuited with parallel lower-voltage transmission lines wherever feasible. A double circuit line has two transmission circuits (each made up of three separate conductors) on a single set of structures. Building a single new transmission line as a double circuit with an existing line is generally more expensive than a single circuit, primarily because it involves rebuilding parts of the existing line that could otherwise be left alone. Nonetheless it is sometimes preferred since it allows two separate transmission circuits to be built within a single ROW.

Electrical losses are incorporated into the cost analysis because the impact of losses can be readily characterized in dollar terms. Since all electrical losses must be offset by generation elsewhere in the system, the relative cost of losses can be approximated by the corresponding costs of electric capacity and energy. This approach was used to calculate the relative economic values of losses that appear in Table 3-5. Some of the transmission alternatives in Table 3-5 would eliminate or defer the need for other currently planned transmission reinforcement projects. The beneficial financial impact of these avoided projects is also shown in the table. The values in the rows labeled “Overall Cost Impact” combine the effect of losses, the construction cost of the line and the cost of currently planned transmission improvements that would be avoided by each alternative.

#### **Summary of transfer capability performance of alternatives**

Table 3-6 summarizes the information previously presented in Tables 3-2 through 3-5. As Table 3-6 shows, the Salem-Fitchburg line shows adequate performance in some respects but does the least to improve voltage stability, dynamic stability and the Arpin phase angle problem. Also, its relatively short length and low construction cost are significantly offset by its relative ineffectiveness in reducing system losses. The Prairie Island-Columbia line ranks near the top in most categories and appears to provide the best overall improvement in transfer capability. All the lines that terminate at Weston have roughly similar performance. Of these, the Chisago-Weston 345 kV line appears to provide the strongest connection at the lowest cost and the Chisago-Weston 230 kV line appears to provide the weakest connection, despite the fact that this alternative outperformed higher-voltage alternatives in the Western Import Sink Sensitivity case. Finally, the Lakefield Junction-Columbia line provides the greatest increase in thermal and voltage transfer limitations and is the most effective line in diverting flows from the congested eastern Nebraska area, but this line is likely to be by far the most expensive line. In addition, this line’s dynamic stability performance, which might be the limiting factor for this line, is relatively poor.

**Table 3-6 Summary of engineering characteristics of transmission alternatives**

<b>Transmission Alternative Engineering Summary</b>	<b>1c</b> Salem-Fitchburg 345 kV	<b>2e</b> Prairie Island-Columbia 345 kV	<b>3j</b> Arrowhead-Weston 345 kV	<b>5a</b> Chisago-Weston 345 kV	<b>5b</b> Chisago-Weston 230 kV	<b>9b</b> Lakefield Jct.-Columbia 345 kV	<b>10</b> King-Weston 345 kV
<b>Thermal Limits</b>							
Southern Imports into WUMS (MW) (with 1000 MW western imports)	2450	2370	2130	2150	2010	2400	2140
Western Imports into WUMS (MW) (with 1000 MW southern imports)	2210	2580	2280	2270	2120	2750	2300
Western Imports into WUMS (MW) (with 1000 MW southern imports) Source Sensitivity	2110	2550	2190	2190	2140	2810	2200
Western Imports into WUMS (MW) (with 1000 MW southern imports) Sink Sensitivity	2160	2720	1860	1880	2160	2590	1890
<b>Additional Performance Considerations</b>							
Dynamic Stability – western transfer level (MW)	2050	2720	2450	2670	2220	2120	2480
Voltage Stability – western transfer level (MW)	2615	3245	2615	2865	2865	3105	2865
Weston 3 Impact – with 2000 MW transfer from west – Improvement relative to existing reclose limit (per-unit power on generator base)	-0.013	0.015	0.036	0.166	0.064	0.009	0.247
<b>Impact on Regional Flowgate Loading</b>							
MAPP OPPD Flowgate	-1.2%	-9.3%	-7.9%	-8.6%	-5.5%	-12.4%	-7.9%
MAPP COOPER_S Flowgate	-7.9%	-18.1%	-14.7%	-16.1%	-11.6%	-22.3%	-15.4%
MAPP ECL-ARP Flowgate	-0.8%	-6.3%	-19.7%	-24.3%	-10.6%	-7.5%	-20.2%
MAPP PRI-BYR Flowgate	1.3%	-26.1%	-15.5%	-18.3%	-9.0%	7.0%	-16.5%
MAPP MNEX Flowgate	0.3%	-17.6%	-17.0%	-20.6%	-6.7%	8.1%	-20.2%
<b>Economic Factors (all values in millions)</b>							
Construction Cost (All Single-Circuit)	\$116 - \$145	\$169 - \$176	\$177 - \$210	\$172 - \$205	\$118 - \$144	\$227	\$136 - \$139
Construction Cost (Maximum Feasible Double-Circuit)	\$158 - \$227	\$243 - \$265	\$266 - \$310	\$240 - \$284	\$171 - \$208	\$395	\$210 - \$262
Relative Cost of Losses	\$50	\$27	\$0	\$1	\$39	\$29	\$21
Cost Impact from Avoided Projects	\$0	-\$1	\$0 (-\$11)	-\$47 (-\$58)	\$0 (-\$11)	\$0	\$0
Overall Cost Impact (All Single-Circuit)	\$166 - \$195	\$195 - \$202	\$177 - \$199	\$126 - \$149	\$157 - \$173	\$256	\$157 - \$160
Overall Cost Impact (Maximum Feasible Double-Circuit)	\$208 - \$277	\$269 - \$291	\$266 - \$299	\$194 - \$228	\$210 - \$237	\$424	\$231 - \$283

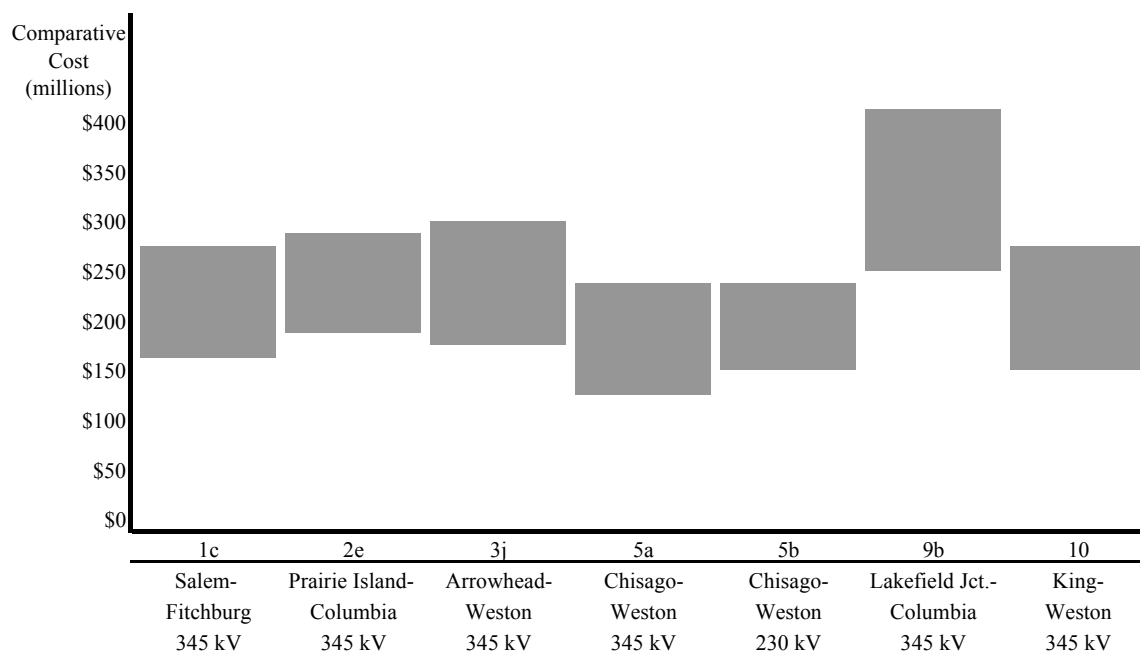
Cost values in parenthesis apply only to particular routes.

Figure 3-2 provides an illustration of the relative transfer performance of the proposed line and alternatives. This figure presents a subset of the data already listed in Table 3-6. While the graphic depiction of the limited data in Figure 3-2 allows for easy comparison between the alternatives, all of the information in Table 3-6 is valuable in assessing the relative merit of the alternatives.



Figure 3-3 compares the overall cost impact of the transmission alternatives (combining the results in the last two rows of Table 3-6). The cost estimates reflected in the table include the effect of other projects that would be avoided by construction of each line, as well as reductions in electrical losses. In addition, the Arrowhead-Weston costs shown in this figure do not correspond to the detailed cost estimates used elsewhere in this EIS. The costs in the figure were estimated by a different group of engineers who employed assumptions that differ from the parameters of the proposed project. Nonetheless, these cost figures are of value, since they allow a fair comparison across the WIRE study transmission alternatives.

**Figure 3-3 Comparative costs of WIRE study transmission alternatives**



#### **Ability to provide local-area support**

As discussed in a previous section, the cost calculation in Table 3-6 incorporates the benefits of new lines with respect to eliminating the need for future reinforcements that would otherwise be required. A relatively small number of near-term projects were identified for inclusion in this cost analysis. However, in the longer term, a larger set of connections to existing lower-voltage lines would be possible, and these would tend to alleviate the need for system improvements that would otherwise be required. These longer-term effects are difficult to evaluate, however, and neither the application nor the WIRE study addresses this issue. Transmission studies conducted as part of AP-8 are not particularly useful either, as they do not consider the period beyond 2008 in any detail.

#### **Geographic diversity**

Beyond the cost and performance indices reported in Table 3-6, one additional engineering consideration is geographic diversity. From the perspective of system reliability, it is preferable to locate a major new line at some geographic separation from existing important lines. This

decreases the likelihood that more than one line would be forced out of service at the same time by severe weather or other localized causes. Accordingly, those proposed lines that are far away from the existing King-Eau Claire-Arpin-Rocky Run 345 kV line should yield a relatively low risk of losing two major interconnections within a short time. Separation from the existing Prairie Island-Byron-Adams 345 kV line is desirable for the same reason. With this consideration in mind, the map in Figure 3-1 shows that the King-Weston alternative is relatively close to the existing King-Eau Claire-Arpin line over most of its length. In contrast, the proposed Arrowhead-Weston line and the Salem-Fitchburg line are relatively far from the existing major lines.

With all else equal, preference should be given to those proposed transmission lines farthest from existing key lines. The appropriate separation distance might be based on the size of a severe storm, perhaps 30-60 miles. Geographic diversity is not a topic that has been well explored, however, and it is difficult to quantify the reliability differences associated with varying degrees of separation. There are many instances in the existing power system of important transmission lines that run in close proximity, some over very long distances.

The map in Figure 3-1 shows another interesting feature of the proposed line and alternatives, as they relate to geographic diversity in Wisconsin. For any line with an eastern terminus at Weston, Wisconsin's power system would be left with a single 345 kV line (the Rocky Run-North Appleton line) connecting eastern and southern Wisconsin to the west. In contrast, the lines that terminate at Fitchburg (with a connection to Rockdale and North Madison) or Columbia would provide two completely independent 345 kV connections between eastern Wisconsin and the region to the west.

In the near term, with patterns of generation and electricity demand similar to today's, this single EHV connection between central and eastern Wisconsin does not represent a major shortcoming for a connection at Weston. This is clear from the fact that the transfer capability levels reported in the WIRE study were achievable even with this Rocky Run-North Appleton line out of service. In fact, outage of the Rocky Run-North Appleton line poses a significantly smaller problem for the system than does outage of 345 kV line segments west of Rocky Run. In part this is because the Rocky Run-North Appleton 345 kV line is paralleled by a number of lower-voltage lines. In addition, however, the fact that there is significant electrical demand and little generation in the Stevens Point and Wisconsin Rapids areas near the Rocky Run Substation plays an important role. This situation results in power flows on the Rocky Run-North Appleton line that are typically much lower than the flows on the line west of Rocky Run.

In the future, however, it is possible that significant generation could be located near Stevens Point or Wisconsin Rapids. This may have the effect of increasing flows on the Rocky Run-North Appleton line, bringing greater prominence to the weak-link nature of this line. In these circumstances, a new high-voltage connection between Minnesota and Weston would be more likely to drive the need to build an additional line paralleling the Rocky Run-North Appleton line than would a new transmission line connecting to Columbia or Fitchburg.

Commission staff has begun to look more deeply at the issue of geographic diversity and the risk of concurrent line outages. Commission staff obtained line outage data from the Wisconsin utilities, which, in aggregate, provide a great deal of information on line outages, durations and causes. From these data it is possible to assess, at least in rough terms, the potential for lines that are close together to be out of service simultaneously due to a common cause related to their geographic location.

Weather phenomena are the most important such cause of line outages. Weather-related causes of transmission outages can be broken into two sets: lightning and wind. Lightning typically causes outages by ionizing the air in the vicinity of power line conductors, destroying the insulating properties of the air and allowing short-circuit current to flow through the air. Circuit breakers must then act, automatically disconnecting the affected line at both ends. Once the lightning strike and short-circuit current have dissipated, the air quickly regains its insulating properties, and the line can often be returned to service in a matter of seconds. Occasionally, equipment damage or other problems force delays in reclosing the line.

Wind, which may include and which may be accompanied by tornados, snow or ice storms, tends to affect lines differently. Wind can blow conductors close to each other, allowing a short circuit to occur. It can also damage structures, insulators or conductors, particularly if it is associated with snow or ice deposition. Such damage, of course, takes time to repair. In addition, wind or ice conditions are likely to persist for some length of time in the vicinity of a line, whereas a lightning strike occurs suddenly but very briefly.

Accordingly, one would expect that lightning-caused outages would generally be quite short, while outages associated with wind would typically last longer. This is confirmed in Commission staff's preliminary analysis of utility outage data. Three-quarters of all lightning-caused outages in this data were less than two minutes in duration, and most of those were less than one minute long. In contrast, the data indicate that outages attributed to wind or ice storms are equally as likely to be longer or shorter than four hours.

The data show a clear relationship between geography and weather outages. Weather-related outages that occur within a few minutes of each other are more likely to affect lines that are geographically close together. With all else equal, it makes sense to site key lines relatively far apart. However, the data do not yield a clear answer as to how far is far enough.

The partial data set compiled by Commission staff at the time of this writing, covering three large utility systems over much of the last decade, shows many instances in which multiple lines were out of service simultaneously, apparently due to a common, weather-related cause. Four of these instances involved two 345 kV lines. These are listed in Table 3-7. Figures 2-1 and 2-2 show the location of these substations. Note that in some cases these lines are close together. Three of the four pairs of lines emanate from a common substation, and two of these form double circuit lines for part of their lengths.

**Table 3-7 Historical weather-related concurrent dual 345 kV line outages**

Time Out	Time In	Line Endpoints	Outage Cause
2/1/86 3:52	2/2/86 22:08	Point Beach-Granville	Ice loading
2/1/86 3:55	2/1/86 4:03	Edgewater-Granville	Wind and ice
4/2/88 18:18	4/2/88 18:18	Paddock-Rockdale	Lightning
4/2/88 18:18	4/2/88 18:22	Columbia-South Fond du Lac	Lightning
3/9/92 18:04	3/10/92 14:23	Columbia-South Fond du Lac	Wind and ice
3/9/92 20:02	3/10/92 11:56	Columbia-North Madison	Wind and ice
11/11/95 1:47	11/11/95 16:45	Arcadian-Zion	Galloping conductors
11/11/95 5:03	11/11/95 5:34	Pleasant Prairie-Zion	Snow

In addition, the Prairie Island-Byron line and the King-Eau Claire line were both forced out of service by lightning within a one-hour period on June 25, 1998. The Prairie Island-Byron line had not yet been returned to service when the King-Eau Claire line tripped, precipitating a severe power system disturbance throughout the MAPP region that caused some customers to lose power and threatened a much broader area. This case is cited in the applicants' discussion of need for transmission system reinforcement in the Arrowhead-Weston application.

Geographic diversity of major lines can help guard against the possibility of such major disturbances. However, to the extent that the concern about geographic diversity is related to preventing such disturbances, it is important to note that forecasting of severe storms has reached a high level, and that system operators could take precautions to reduce the risk of such a disturbance given sufficient warning. For example, it is clear in retrospect that the storm of June 25, 1998, was a very severe storm. Considerably more line outages occurred that day than any other day reflected in the line outage data, most of them unrelated to the disturbance in the MAPP region. Most probably, the power of this storm was clear from forecasts before the storm arrived. With a thorough understanding of the risks, and a procedure to reduce inter-regional power transfers in the case of severe weather, such a disturbance could have been avoided.

## **Validity of WIRE study assumptions**

The WIRE study attempted to simulate year 2002 conditions on the regional power system. As part of this task, the participants made assumptions about transmission reinforcement projects that were not yet complete at the time of the study. These were projects that were already in the utilities' plans, and which had, in some cases, received all necessary approvals for construction to begin. Most of these projects were upgrades of existing lines or changes to substation equipment, but some involved large new transmission lines whose approval was not yet certain. To the extent that the study results hinge on the accuracy of the power system model that incorporated these assumptions, the current status of these projects deserves scrutiny. The current status of these projects, and the associated impact on the results reported in the WIRE study, are discussed below.

In addition to changes in the transmission system, new power plants may also affect the flow of power in the system and the ability of the system to support power imports. A large number of new power plant projects are currently under consideration in and around Wisconsin, but many of these remain uncertain as of the publication date of this EIS.

### **Chisago-Apple River transmission line**

While most of the transmission projects assumed in the WIRE study were minor upgrades of existing facilities, there are some exceptions. The Chisago-Apple River transmission line is perhaps the most significant of these exceptions. NSP and DPC initially sought approval for this line to be built as a 230 kV line, and they received approval for this plan from the PSCW. This project encountered considerable public opposition, however, including two lawsuits by project opponents, and the prospect for approval by Minnesota regulators became uncertain. Earlier this year, a settlement was negotiated between one party that had filed suit and the applicants. As part of this settlement, Chisago project applicants agreed to make certain modifications to the proposed line, including building it to operate at a voltage of 161 kV rather than 230 kV, as assumed in the WIRE study.

At either voltage level, a Chisago-Apple River line would contribute to the ability of the transmission system to transfer power into Wisconsin. However, a lower-voltage line would not carry as much power as the originally proposed 230 kV line. As a consequence, the transfer levels identified in the WIRE study, which assumed that a Chisago-Apple River 230 kV line was in place, will probably tend to be higher than those achievable with a Chisago-Apple River 161 kV line. This should have a roughly equal effect on all of the transmission alternatives, however, so the relative ranking of the transmission alternatives may be little changed.

Commission staff performed an assessment of the impact that a reduction in voltage of a Chisago-Apple River line would have on the kind of transfer limits calculated in the WIRE study. This consisted of a brief examination of the impact of changing the voltage of the Chisago-Apple River line on thermal limits and voltage stability. In addition the change in system power flows in the immediate aftermath of a change in network configuration was assessed. While this is not identical to the dynamic stability study conducted by the WIRE group, it provides insight into the dynamic performance characteristics of various transmission reinforcements, and should give a reasonable indication of the likely impact on dynamic stability performance.

At the time that Commission staff analyzed this issue, the proposed settlement involved a new 115 kV line between Chisago and Apple River and the analysis was conducted based on this voltage. A Chisago-Apple River 161 kV line should be expected to yield results intermediate between the original WIRE study results (based on a 230 kV line) and Commission staff's results (based on a 115 kV line).

Not surprisingly, the results of Commission staff's analysis indicate that a reduction in the voltage of the Chisago-Apple River line would likely reduce the performance of the transmission system modeled with the Arrowhead-Weston line in place. However, this effect is modest, appears to affect different transmission reinforcements similarly, and would not change the

WIRE study results enough to fundamentally change conclusions that could be drawn from these results. For example, a number of thermal limits appear at high levels of imports from the west. In general, the same line overloads appear regardless of the voltage assumed for the Chisago-Apple River line, although they appear at a lower overall transfer level with a 115 kV Chisago-Apple River line. This difference averages 40 MW.

Similarly, examination of the voltage stability cases used in the WIRE study reveals slightly lower voltages with a 115 kV Chisago-Apple River line, but the low voltages differ by an average of 0.25 percent of nominal voltage, and no differences are larger than 1 percent of nominal voltage. This difference would be insufficient to fundamentally alter the original WIRE study conclusions with respect to voltage stability.

The final piece of Commission staff's assessment found essentially the same result: changing the Chisago-Apple River line from 230 kV to 115 kV tends to reduce the performance of the system, but this effect is small relative to the effect of the different EHV transmission lines assumed in the WIRE study. The effect of changing the voltage from 230 kV to 161 kV should be less than the effect of changing the voltage to 115 kV. As a consequence, the changed plans for the Chisago-Apple River line should not be expected to have a significant effect on the performance, and relative performance, of the WIRE study transmission lines.

It is not yet clear whether this project will proceed, even at a voltage lower than 230 kV. Commission staff did not analyze the effect that having no Chisago-Apple River line would have on the transfer capability of the Arrowhead-Weston project or of the other alternatives discussed in this chapter. If no new Chisago-Apple River line were built, the transfer capability of the proposed Arrowhead-Weston line and the alternatives would suffer. However, the Chisago-Apple River applicants will have to carry out some transmission or generation improvements in the near future to alleviate problems in northwestern Wisconsin. Whatever action they take will likely tend to improve transfer capability somewhat. Moreover, completely eliminating the Chisago-Apple River line from the models should affect all alternatives in a roughly similar way.

### **Additional projects**

In the course of the WIRE study, additional projects, which had not initially been planned to be completed by 2002, were found necessary to optimize the effect of adding a major new transmission line and to allow the transfer levels reported in that study. These projects included upgrades of existing lines and substation equipment. Table 3-8 lists these projects and their current status.

As indicated in the table, the current status of these projects ranges from “no longer required” to “currently under construction.” For those projects included in the utilities’ SEA filings, construction is expected to begin by the end of 2002. For some projects, there are no current plans to begin construction. It is important to recognize that without the Arrowhead-Weston line (or a similar high-voltage line) and the new path for power transfer that it would provide, there may be no reason to undertake some of these upgrades – no matter how minor – as they do not limit the capability of the system. Accordingly, the fact that a project is not currently planned is not a significant impediment to achieving the system performance (import)

capabilities reported in the WIRE study. The eastern Wisconsin transmission systems of MGE, WEPCO, WP&L and WPSC will be combined to form the ATCo system. (See Chapter 2.) This company will have a strong incentive to increase the capability of the system, as this will increase the company's revenues. Therefore it is likely that the transmission company will actively seek remedies to any system limitations that actually arise.

**Table 3-8 Transmission upgrade projects associated with the proposed project**

Item	Upgrade Description	Upgrade Type	County (State)	Utility	Estimated Cost (\$)	Project Status
1	Reconductor Eau Claire-Wheaton 161 kV line	Transmission line	Eau Claire	NSP	387,000	Included in NSP's SEA filing, construction to begin by 2002.
2	Reconductor Wheaton-Wheaton Tap 161 kV line	Transmission line	Chippewa	NSP	198,000	Included in NSP's SEA filing, construction to begin by 2002.
3	Convert Oak Creek-Arcadian line to 345 kV operation	Transmission line	Racine, Waukesha	WE	21,615,000	Received PSC approval fall 1999. Currently under construction.
4	Upgrade Forest Junction-Highway V 138 kV line	Transmission line	Calumet, Brown	WE	215,000	No current plans.
5	Reconductor Rocky Run-Whiting Ave. 115 kV line	Transmission line	Portage	WPSC	200,000	Included in WPSC's SEA filing, construction to begin by 2002.
6	Upgrade Weston-Northpoint 115 kV line	Transmission line	Marathon, Portage	WPSC	2,400,000	WPSC states that this is included in their long-range plans for construction in 2003.
7	Rebuild Kelly-Whitcomb 115 kV line	Transmission line	Marathon, Shawano	WPSC	4,100,000	Included in WPSC's SEA filing, construction to begin by 2002.
8	Reconductor .1 mile of Itasca-Lombard line	Transmission line	(Illinois)	CE	10,000	Unknown.
9	Retension Goodings Grove-Lockport lines	Transmission line	(Illinois)	CE	50,000	Unknown.
10	Upgrade Barron-Apple River terminal equipment	Substation equipment	Polk, Barron	DPC	10,000	DPC states that they would carry out this upgrade as required to eliminate limitations.
11	Upgrade Sand Lake-Port Edwards terminal equipment	Substation equipment	Wood, Waushara	WP&L	50,000	No current plans.
12	New Rockdale transformer	Substation equipment	Dane	WP&L	4,000,000	No longer required, because of new RockGen power plant.
13	Upgrade Pulliam terminal equipment	Substation equipment	Brown	WPSC	10,000	Expected complete fall 2002.
14	*Upgrade Weston-Rocky Run terminal equipment	Substation equipment	Marathon	WPSC	300,000	WPSC states that this would be carried out contemporaneously with Arrowhead-Weston line.
15	*Upgrade Weston 345/115 kV transformer	Substation equipment	Marathon	WPSC	2,000,000	WPSC states that this would be undertaken in conjunction with proposed project, as required.
16	Upgrade Itasca-Lombard breakers	Substation equipment	(Illinois)	CE	2,000,000	Unknown.
17	Shauburg substation changes	Substation equipment	(Illinois)	CE	1,000,000	Unknown.
18	Des Plaines substation changes	Substation equipment	(Illinois)	CE	50,000	Unknown.
19	Capacitors -- various locations	Substation equipment	(Wisconsin)	multiple	8,670,000	Unknown.

\* The cost of these projects is already included in Arrowhead-Weston project cost estimates.

In addition, the Commission has the authority to order a Wisconsin utility, including the transmission company, to carry out any construction that the Commission finds necessary to relieve constraints on the transmission system.<sup>55</sup> If necessary, the Commission could exercise this authority at the time of any approval for a major transmission line project.

Finally, the WIRE study results remain, fundamentally, an approximation, based on a single model of power system conditions that are constantly changing. A number of other changes in the generation and transmission system that have occurred or are now planned will alter actual flows on the power system in ways that have not been thoroughly examined. Accordingly, this study is best viewed as an analytical tool for assessing the relative performance of different transmission line alternatives. Updated analyses may show that some of the improvements listed in Table 3-8 are no longer required.

#### **Plano-Plano Tap line**

One major new transmission line that was identified as necessary in the WIRE study does not appear in Table 3-8. This line would connect the existing Plano Substation west of Chicago to a new substation, dubbed Plano Tap, which is also in northern Illinois. This is a double circuit 345 kV line that is included in CE's long-range plans. During the WIRE study, this line was found to alleviate a potential transmission line overload in Illinois that limits power import capability into Wisconsin. Accordingly, this line was added to the list of projects that would be required to allow the identified transfer capability levels to be met, and it was incorporated into all power system models used in subsequent phases of the study. After the limitation alleviated by this line was identified, CE personnel noted that this limitation could also be alleviated by an operating guide, involving transformer switching, and that the Plano-Plano Tap line would not be required to achieve the transfer levels identified in the WIRE study. For this reason it does not appear that this line should be regarded as a necessary accompaniment to the proposed project or any of the WIRE Study alternatives.

## **Engineering analysis conclusions**

The engineering analysis conducted as part of the WIRE study provides insight about the suitability of the transmission lines discussed in this chapter to serve as alternatives to the proposed Arrowhead-Weston line. By most measures, all of the identified transmission alternatives could provide transfer benefits roughly comparable to those of the proposed line. Not all of these should be regarded as reasonable alternatives to the proposed line, however.

In particular, alternatives 1c (Salem-Fitchburg) and 9b (Lakefield Junction-Columbia) have attributes that render them significantly less desirable than the others, such that they are not reasonable alternatives to the proposed line.

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<sup>55</sup> Wis. Stat. § 196.494 (3).

### **Shortcomings of Lakefield Junction-Columbia line**

Perhaps the most revealing assessment of the Lakefield Junction-Columbia line emerges from comparison with the Prairie Island-Columbia line. Relative to Prairie Island-Columbia, Lakefield Junction-Columbia appears to offer some significant disadvantages and virtually no advantages.

Electrically, these two options both met the WIRE study criteria and generally performed similarly. Perhaps the most significant electrical performance difference concerns dynamic stability. In general, these transmission lines exhibited similar performance in the dynamic stability analysis at base transfer levels. As transfers were increased, however, the Prairie Island-Columbia line appeared to be the strongest of all options in providing system damping for a few key disturbances while the Lakefield Junction-Columbia line was next to last.

The two lines might follow similar routes between the La Crosse area and Columbia. The distance from the La Crosse area to Lakefield Junction, however, is nearly twice as long as the distance to Prairie Island. Indeed, the Lakefield Junction-Columbia line appears to be the longest and most expensive of the alternatives considered.

From this perspective, the only real route advantage that Lakefield Junction-Columbia offers relative to Prairie Island-Columbia is a significantly higher potential for corridor sharing in Minnesota, and this is probably offset by its greater length. If this is true, and given that Lakefield Junction-Columbia offers no significant electrical performance advantages and some notable disadvantages relative to Prairie Island-Columbia, then there is no reason to give further consideration to a Lakefield Junction-Columbia line as a system alternative.

This assessment is based on the present-day configuration of the transmission system, of course, and could be changed by future developments. For example, this line would appear in a much more favorable light if Minnesota utilities were to make independent plans to build a 345 kV line between Lakefield Junction and the existing Adams substation in southeastern Minnesota.

### **Shortcomings of Salem-Fitchburg line**

As discussed earlier in this chapter, the Salem-Fitchburg alternative performed slightly below the WIRE study standard with respect to the Arpin phase angle problem. This should not be regarded as a critical flaw, however, because the performance shortfall was small – perhaps within the range of uncertainty of the study. In addition, there may be other ways to overcome this problem.

More significant is the poor dynamic stability performance of this alternative. For many disturbances tested, this line offered little improvement relative to the unreinforced base case. Indeed, for a few faults, the presence of the Salem-Fitchburg line caused a deterioration of some aspects of dynamic stability performance relative to the base case.

Dynamic stability concerns are of increasing importance on the MAPP-MAIN interface. At present the system is often close to being limited by dynamic stability concerns and this should be expected to continue. In this light, the inability of the Salem-Fitchburg line to contribute significantly to improving system dynamic performance appears to be a serious drawback.

Dynamic stability limits are a particular concern because it is more difficult to assess how close the system is to a dynamic stability limit than to a thermal limit. Accordingly, it is prudent to operate the system so as to maintain a large margin of protection against possible dynamic stability problems. As a consequence, a low dynamic stability limit may be more constraining than a low thermal limit.

In addition, the Salem-Fitchburg line was relatively ineffective in reducing flows on flowgates that sometimes limit imports into Wisconsin, and was the least effective of all alternatives in promoting voltage stability.

Taken together this information suggests that the performance of a Salem-Fitchburg alternative is last among the lines considered in terms of its electrical performance. Accordingly, despite the fact that the transfer capability benefits of this line are, by some measures, roughly comparable to the proposed line, this alternative does the least to alleviate the need for additional future reinforcement projects. This suggests that the Salem-Fitchburg alternative should be dropped from consideration.

## High Voltage Direct Current System Alternative

All of the transmission alternatives discussed so far would be designed to carry AC. However, any of these lines, or an alternative line, could be built as an HVDC line instead.

AC has been adopted almost universally for generation, transmission, and distribution of electrical energy because of economics, ease of expansion, and interconnect ability. The transmission of electrical power between remote generating stations and distant receiving stations is, however, usually either three-phase AC or HVDC. HVDC transmission lines are now routinely used between generating stations and load centers that are separated by long distances.

During the past 15 years, interest in HVDC transmission has significantly increased. The application of HVDC transmission can be attributed to one or more of the following reasons:

- HVDC transmission may be less expensive than AC transmission.
- HVDC has many functional benefits.
- HVDC transmission may have environmental benefits compared to AC transmission.

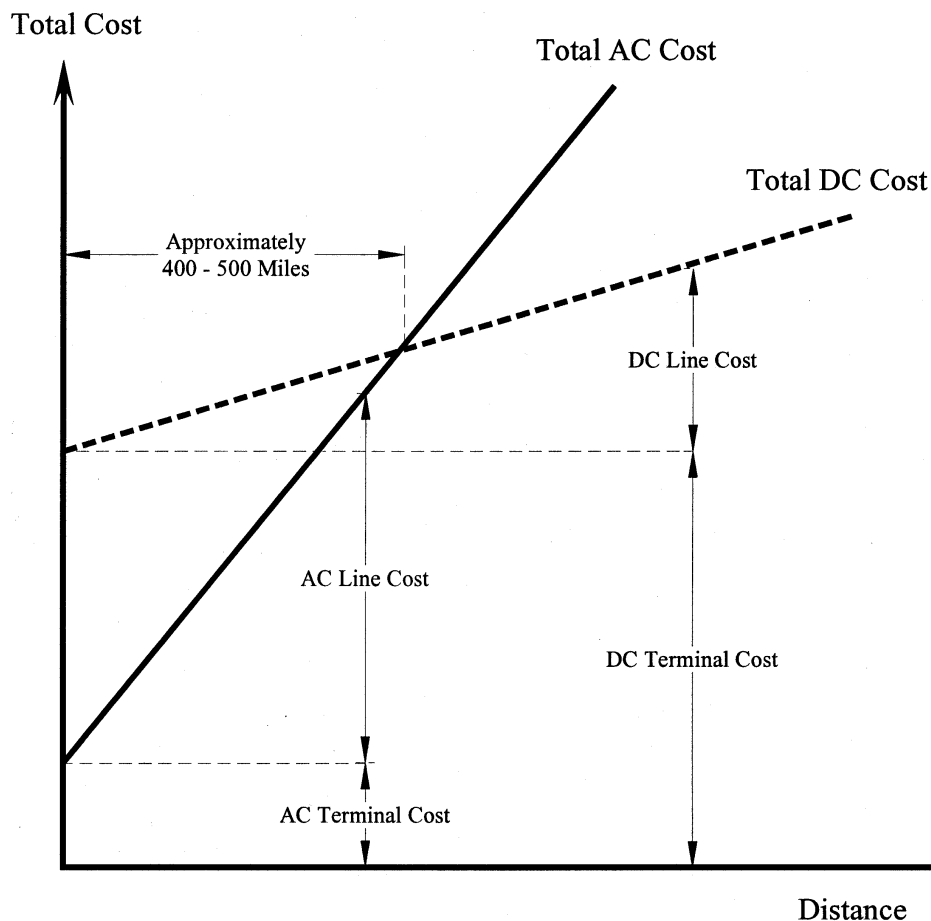
## Economics

### Overhead lines

A direct current (DC) transmission line costs less than an AC line for the same transmission capacity. However, the terminal stations are more expensive for HVDC due to the fact that they

must convert power from AC to DC and vice versa. Above a certain “break-even distance,” however, the HVDC alternative will always give the lowest cost. (See Figure 3-4.)

Figure 3-4 Estimated break-even distance for overhead line transmission



There is no universally correct break-even distance, since the economic comparison between DC and AC alternatives depends largely on local conditions, such as requirements placed on line performance and properties of connecting AC systems.

Studies show that under normal conditions it is advantageous to consider DC for overhead lines when the transmission distance is 400-500 miles or more. In areas with a high cost for acquiring ROW, HVDC becomes feasible at a shorter distance.

### Underground transmission

For underground or submarine cables, savings in cable and associated costs can much more easily offset the extra cost of DC converter stations. The considerable difference between underground cable costs for HVDC and AC transmission is more pronounced than for

overhead line costs. Break-even distances for HVDC cable transmission systems average 20 miles. Distances of roughly 40 miles or more, which are not feasible for uncompensated AC transmission, may be good candidates for an HVDC application.

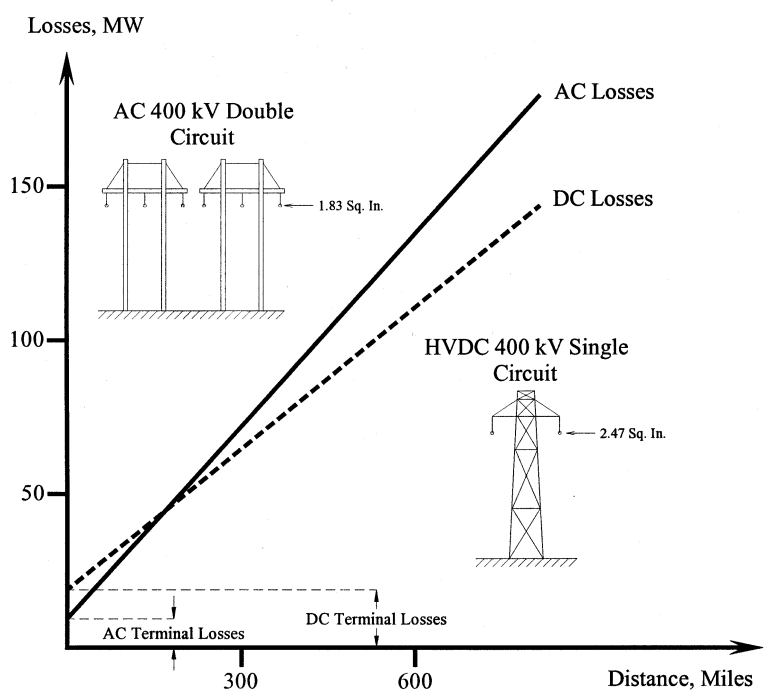
The longest HVDC submarine cable presently in operation is the 156-mile Baltic Cable transmission line between Sweden and Germany. Several HVDC submarine cables of 300 miles or more are currently being planned in Europe and Asia.

Submarine cables of this length make sense since there is no practical way to build an overhead line across the sea. However, because material and construction costs are much higher for underground cable transmission systems than for overhead lines, building the Arrowhead-Weston line as an underground cable system would be much more expensive than alternatives considered in this chapter and the next. In addition, the environmental impacts of underground construction are substantial. For these reasons, underground construction is not a reasonable alternative to the applicants' proposed project.

### Lower losses

An HVDC transmission line has lower losses than AC lines for the same power capacity over a distance of 150 miles. Figure 3-5 shows a comparison of the losses for overhead AC and HVDC transmission lines carrying 1,200 MW. The losses in the converter stations are estimated to be approximately 0.6 percent of the transmitted power in each station.

Figure 3-5 Loss comparison between AC and HVDC



The applicants state that HVDC transmission and associated converter stations are very expensive and complex. Studies show that a pair of converter stations requires a capital investment of \$200-\$300 per kilovolt-ampere (kVA). The application estimates that an HVDC line between western MAPP and eastern Wisconsin would cost approximately \$650 million for an HVDC line capable of transferring about 1,000 MW compared to AC transmission reinforcement, which is estimated to cost roughly \$200 million. The applicants also conclude that the high capital cost of HVDC transmission requires a firm power sale that is financially viable.

## **Functionality**

HVDC systems offer functional characteristics and performance not achievable with AC systems. These include: control of power flow and modulation; capability for asynchronous interconnections; and low short-circuit currents. However, harmonics associated with an HVDC system can be problematic.

### **Control of power flow and modulation to increase power flow**

One of the fundamental advantages with HVDC is that it is very easy to control the flow of power in the link. Depending on the application and the network requirements, the control system can include a number of functions. In some projects, the main control is based on a constant power transfer. However, in many cases the link can be used to improve the AC system performance by means of additional control features. Normally these controls are activated automatically when certain criteria are fulfilled. Such automatic control functions include constant frequency control, redistribution of the power flow in the AC network, and damping of power swings in the AC networks. In many cases, in which system stability concerns pose a limit to power transfer, such additional control functions can make it possible to increase the safe power transmission capability of AC transmission lines.

### **Asynchronous interconnection**

Several HVDC links interconnect AC systems that are not running in synchrony with each other. For example, the power system in the western United States is not synchronous with the power system in the eastern United States even though the nominal frequencies are the same. This is because it is sometimes difficult or impossible to make a synchronous connection between two AC networks due to stability reasons. In such cases HVDC may be the only way to exchange power between the two networks.

When interconnecting two power systems with different nominal frequencies (typically 50 and 60 herz (Hz)), HVDC offers technical advantages even where the length of the DC line is small.

### **Low short-circuit currents**

When a high power AC transmission line is constructed from a power plant to a major load center, the short-circuit current level will increase in the receiving system. High short-circuit currents are becoming an increasingly difficult problem in many large cities. They may result in

a need to replace existing circuit breakers and other equipment whose rating is too low. If, however, new generating plants are connected to the load center via a DC link, the HVDC connection would not contribute to the short circuit current of the interconnected AC system.

### **Harmonics**

Another effect from a DC system is harmonics on both the AC and DC side of the converter. Harmonics are power variations at a given multiple of the ordinary 60 Hz power system frequency. Their effect on the power system and adjacent communication systems is of concern. The 12-pulse converter produces current harmonics (11<sup>th</sup>, 13<sup>th</sup>, 23<sup>rd</sup>, 25<sup>th</sup>, 37<sup>th</sup> etc.) on the AC side. The converter also produces voltage harmonics on the DC side (12<sup>th</sup>, 24<sup>th</sup>, 36<sup>th</sup> etc.). Large filters are used to prevent the harmonics from entering the network system.

## **Environmental**

### **Routing and ROW**

A major difference between AC and DC transmission systems is the reduced ROW requirements of DC overhead lines for the same power capacity. ROW widths can vary greatly, depending on line design and local conditions. A DC transmission line encompasses nearly the same set of concerns as an AC transmission line and the routing of a DC transmission line entails many of the same challenges as AC transmission, such as agriculture impact, wetland impact, cultural resources, and river crossings.

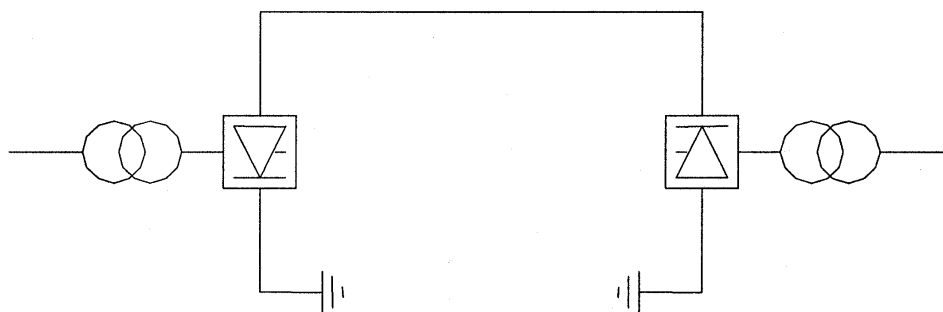
Electromagnetic fields (EMF) produced by HVDC systems are not the same as those produced by AC circuits. An AC system produces time-varying (60 Hz) magnetic fields. Some studies have shown a weak link between exposure to 60 Hz EMF and certain diseases (see Chapter 5 for a discussion of alternating-current EMF and health effects). A DC system produces a static magnetic field (non-time varying). This is the same kind of magnetic field produced by the earth. The earth's magnetic field is most intense at the poles and decreases in the middle latitudes. The earth's magnetic field in North America is generally in the range of 500–550 milligauss, which is significantly higher than the field to which HVDC lines would expose humans beneath the line. There is no evidence of any health concerns related to exposure to static magnetic fields.

## **Categories of HVDC transmission systems**

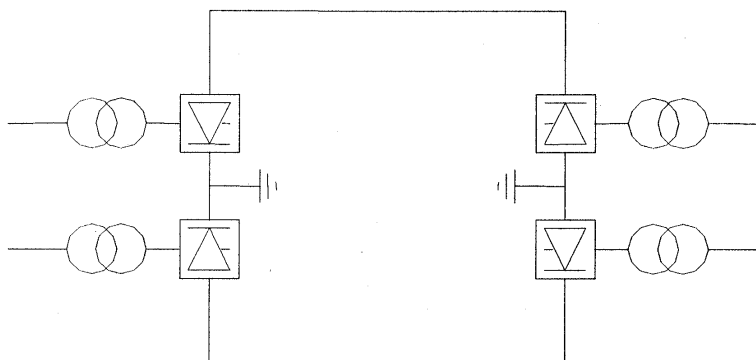
There are three different categories of HVDC transmission systems: point-to-point transmission; back-to-back stations; and multi-terminal systems.

### **Point-to-point transmissions lines**

Most HVDC transmission lines connect two points using overhead lines, submarine cables or a combination of lines and cables. Many of the cable systems are monopolar, with only one metallic conductor between the converter stations, using the ground or sea as the return path for the current.

**Figure 3-6**      **Underground/submarine monopolar cable**

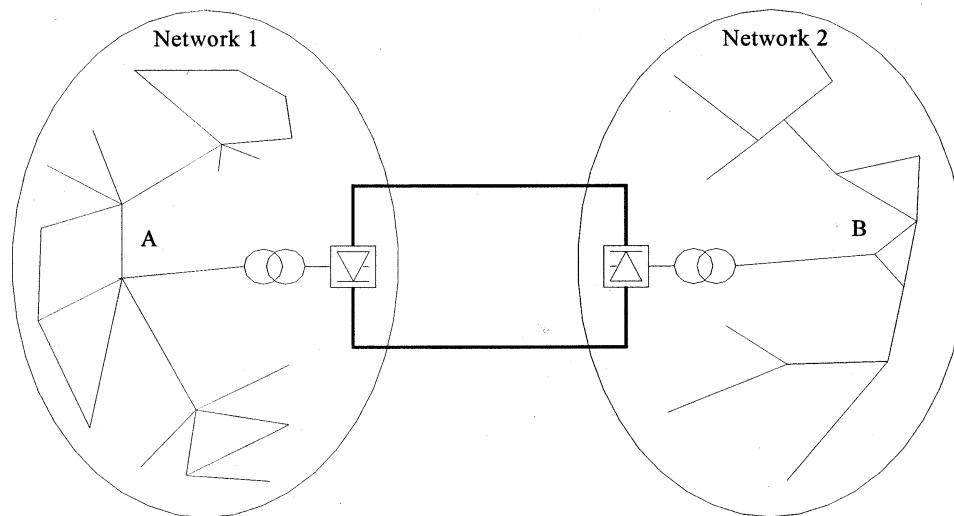
Most overhead line HVDC transmission lines are bipolar, i.e. they use two metallic conductors of opposite polarity (one positive and one negative). A bipolar system is actually a double circuit transmission line, since one pole can continue to transmit power when the other pole is out of service. When one pole of a bipolar terminal is out of service the return path reverts to the earth.

**Figure 3-7**      **Overhead bipolar DC transmission line**

### **Back-to-back stations**

There are several back-to-back stations in operation around the world. In these installations both the rectifier and the inverter are located in the same station. They are normally used to create an asynchronous interconnection between two AC networks, which could have the same or different frequencies.

A back-to-back station is normally somewhat simpler than a converter station for a point-to-point transmission project. The direct voltage level can be selected without consideration to the optimum values for an overhead line or cable, and are therefore normally quite low, 150 kV or lower.

**Figure 3-8 Back-to-back DC stations****Multi-terminal systems**

A multi-terminal HVDC transmission system is an HVDC system with more than two converter stations. Such a system is much more complex than an ordinary point-to-point transmission line. In particular, the control system is more elaborate and the telecommunication requirements between the stations become larger. In addition, each new converter station adds significantly to the cost of the system.

Only one large-scale multi-terminal HVDC system is in operation in the world today, the 2,000 MW Hydro Quebec-New England transmission line built between 1987 and 1992. A number of future multi-terminal HVDC transmission systems are being actively considered at this time.

**Conclusion**

Relative to AC, HVDC offers both advantages and disadvantages. The advantages include significantly improved control over the flow of power and considerable reduction in time-varying magnetic fields, as well as reduced ROW requirements. The primary disadvantage is the greatly increased difficulty and cost of making interconnections along the line. In addition, the complexity of HVDC systems makes them more susceptible to failure than AC lines. Finally, the costs – including the cost of electrical losses – can vary greatly between AC and HVDC systems. AC systems are much less expensive for short and moderate distances, but a point-to-point HVDC system will eventually become less expensive as line length increases, provided no mid-line interconnections are required. Underground HVDC lines can be less expensive than underground AC lines even at short distances. However, underground lines are so much more expensive than overhead construction that the cost of an underground HVDC line would likely be prohibitive for a line the length of the proposed project.

# Environmental Analysis of Transmission System Alternatives

## Purpose

A system-level environmental review of transmission system alternatives should be conducted prior to moving forward with a construction proposal. The purpose of such an analysis is not to determine the exact environmental effects of a specific line, but to evaluate the relative risk of environmental impact between geographically diverse transmission options. The results of such an analysis can then be used to select the most appropriate project to bring forward for construction case review, where the environmental effects of specific routes for that project can be evaluated. In this case, however, the environmental system analysis and construction analysis are combined into one regulatory proceeding.

## Methods and evaluation criteria

The methods used in conducting system-level environmental reviews are fundamentally different from those used in the review for a specific transmission line. In reviews of specific lines only one system option is evaluated and most or all potential locations for the line are known. Environmental reviews for a specific line focus on impacts associated with a set of carefully selected alternate routes with a designated centerline and ROW. The width of ROWs will vary, depending on the project, from 80 to 150 feet. This type of environmental review focuses on the specific nature and degree of environmental impact likely to be caused by the construction and operation of a proposed transmission line. (See Chapters 6 to 9 and 11.)

In a system-level review a number of different system options are evaluated. System options can include both transmission and non-transmission solutions to an existing or anticipated problem in the electric network. Non-transmission solutions can include equipment changes at existing substations, upgrading existing transmission, changing the operating parameters of the transmission system, energy efficiency, or new generation. Non-transmission construction solutions are less likely to have significant environmental impacts and so are often preferred, from an environmental perspective, over solutions that require construction of major transmission facilities.

When a transmission system problem is identified, an analysis is usually conducted to determine potential solutions to the problem. If non-transmission solutions are judged to be inadequate for solving the problem then a number of transmission line solutions is usually identified. Very often these transmission solutions are located in different parts of the state, but they are designed to solve the same electrical problem. A “no action” option is generally considered as well. Before an environmental review is prepared, a detailed engineering review of the electrical problem selects all reasonable options that solve the electrical problem under review. After the final list of candidate solutions is determined, an environmental review is conducted to evaluate the relative environmental performance of each solution.

Because a system review might need to look at hundreds or even thousands of square miles of landscape, a different approach than the one used for an individual transmission line review has been used. The specific route for each transmission line option is not known, so a study area approach is used instead. For each system option a study area is defined by first establishing a representative centerline or location for the potential power line. An effort is made to pick a reasonable location for each line option. After the centerline is chosen, a study area is established that extends a specified distance from either side of the centerline for its entire length. The width of the study area used is a matter of judgment. It needs to be large enough to encompass most reasonable variations in the location of a potential line but must be narrow enough to facilitate analysis. If a study area is too large it becomes very cumbersome to analyze and regional differences between study areas may be lost.

Because study areas are analyzed rather than specific transmission line routes, the environmental review cannot determine the exact magnitude of environmental impact for each option. Instead, the analysis focuses on the relative risk of environmental impact associated with the construction and operation of each system option. This is accomplished by selecting factors that can be used to measure the quality of the natural environment within each option study area. If one study area is found to support a landscape of relatively high natural resource value when compared to other study areas, it follows that the relative risk of incurring environmental damage in that study area is also higher.

For this project, a representative centerline for each system option was chosen and a study area was defined to encompass the landscape within 2.5 miles on either side of the assumed centerline. (See Figure Vol. 2-13.) These 5-mile-wide study areas were identified in the WRAO/WIRE study report filed by the utilities in March 1999. The system environmental review for this EIS evaluated portions of 24 counties and covers approximately 4,000 square miles.

## **Environmental review factors**

Commission environmental staff, with input from the DNR field staff, Bureaus of Endangered Resources (BER) and Integrated Sciences Services, and the NPS, selected eleven environmental factors to use in this analysis. These factors are listed in Table 3-9. In addition, agricultural and social factors were considered. An attempt was also made to gauge the availability of corridor sharing opportunities within each study area.

**Table 3-9 Environmental factors used in this analysis**

Environmental Factors	Data Source
Land cover	DNR 1991-93 WISCLAND digital land cover (GIS satellite grid coverage)
County forests	DNR (digital GIS coverage)
State properties	DNR (GIS digital property delineation)
State trails	DNR (digital GIS coverage)
National scenic riverways	NPS
National scenic trails	Ice Age Trail Foundation (digital GIS coverage)
Nationwide Rivers Inventory (potential candidates for national wild, scenic, and recreational river status)	NPS (digital GIS coverage)
Outstanding and exceptional resource waters	DNR (digital GIS coverage)
Wisconsin National Heritage Inventory (endangered, threatened, special concern species and communities)	DNR 1999 (digital coverage)
Road densities	DOA- 1995 TIGER satellite county road data
Human population densities	DOA – U.S. 1990 census data

Environmental factors such as human population density, road density, land cover, and land ownership have been used in other studies involving landscape scale spatial analyses.<sup>56,57</sup> These data afford analysts an opportunity to conduct environmental reviews encompassing large areas. All data sets use standard formats and are based on satellite imagery or other statewide databases that allow comparisons to be made between different regions of the state. Each environmental factor gives a different measure of either the quality of the natural environment or the level of human disturbance in each study area. In general, a system option with a study area passing through a landscape where the natural environment has been permanently altered by development is at a lower risk of incurring significant environmental impact on biological resources than an option with a study area passing through a relatively natural landscape. Areas with relatively larger human populations and high road densities would also indicate higher levels of disturbance to the natural environment. Each system option's potential for incurring environmental impact is evaluated based on its overall performance across all factors.

A total of ten study areas were analyzed. These study areas, in different combinations, comprise the different system options under review (see Figure Vol. 2-13).

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<sup>56</sup> Mladenoff, D.J., T.A. Sickley, R.G. Haight, and A.P. Wydeven. 1995. A Regional Landscape Analysis and Prediction of Favorable Gray Wolf Habitat in the Northern Great Lakes Region. *Conserv. Biol.* 9:279-294.

<sup>57</sup> O'Neill, R.V., J.R. Krummel, R.H. Gardner, G. Sugihara, B. Jackson, D.L. DeAngelis, B.T. Milne, M.G. Turner, B. Zygmunt, S.W. Christensen, V.H. Dale, and R.L. Graham. 1988. Indices of Landscape Pattern. *Landscape Ecol.* 3:153-162.

Data were acquired in digital format from the DNR, Minnesota Department of Natural Resources, the NPS, the Ice Age Trail Foundation, DOA, and the University of Wisconsin-Madison. Computer analyses were performed using ArcView GIS and ArcView Spatial Analyst.

## Transmission line system options

Four new transmission-only system options are reviewed in this chapter. They are Arrowhead-Weston 345 kV, Chisago-Weston (230 or 345 kV), King-Weston 345 kV and Prairie Island-Columbia 345 kV. Each system option has two landscape variations. (See Figure Vol. 2-13.) For purposes of the system environmental review the following eight options were evaluated (Table 3-10):

**Table 3-10** Transmission system options

System Option	Approximate Length (miles)
Arrowhead-Weston via Tripoli	217
Arrowhead-Weston via Owen	195
Chisago-Weston via Tripoli	192
Chisago-Weston via Owen	170
King-Weston-North	165
King-Weston-South	160
Prairie Island-Columbia- via Wisconsin	197
Prairie Island-Columbia-via Minnesota	197

For more detailed maps showing each option's study area see Figures Vol. 2-14 – Vol. 2-17.

These system options were developed by the utilities as part of the WRAO's WIRE study. In addition to these options, an integrated generation and transmission system alternative are described in Chapter 4. An environmental review of those components is also included in Chapter 4.

## Land cover analysis

Each system option was analyzed to determine the proportion of seven land cover classes found within each 5-mile-wide study area. Land cover classes were identified as: urban (city or village); barren (land with less than 30 percent vegetative cover – sand; bare soil; exposed rock); grassland (non-cultivated herbaceous vegetation dominated by grasses – includes pasture; restored prairie; lands in the Conservation Reserve Program and idle farmland); forest (upland broadleaved deciduous and coniferous forests, and forested wetlands); wetlands; shrub land; and agriculture (row crops, hay/alfalfa, and cranberry bogs) from the 1998 WISCLAND (Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data) digital land cover data.

From an environmental perspective, transmission lines constitute an industrial-type land use and are more compatible with areas that have undergone significant alteration from their natural

state. The more natural the landscape, the less compatible the area may be with transmission line development and the higher the risk of significant environmental damage to natural resources. Examples of altered landscapes include areas with urban and agricultural land uses. More natural landscapes include areas of forest, wetland, and open water.

An argument can be made that nearly the entire state has undergone significant alteration due to human settlement and development. Indeed, during the early part of the 20<sup>th</sup> century most forestlands in Wisconsin were clear cut. This impact was significant, but while much of the original forest cover in the southern and central parts of the state has been kept permanently cleared, the northern third of the state is returning to a primarily forested landscape. As a result, northern Wisconsin has regained much of the ecological function it lost during the early logging era. Today modern forestry practices focus more on sustainable and ecologically sound management of forest lands. (See Chapter 5 – Forest Resources.) From a human perspective, forests are an important economic asset and are highly valued for recreation and the production of forest products. Figure Vol. 2-18 shows the general land cover of the state derived from satellite data collected between 1991 and 1993. The northern third of the state supports large unbroken areas of forest and wetland habitat, in contrast to the southern and central parts of the state where agriculture and urban/suburban development are more prevalent.

Figure Vol. 2-19 shows the proportion of each land cover type within each system option study area. Of the study areas under review, the King-Weston options have the highest proportion of altered landscapes. The North and South variations for the King-Weston study areas are similar in terms of land cover. For the King-Weston/North option, urban and agricultural development accounts for 49 percent of the land cover, while 53 percent of the land cover in the King-Weston/South study area is in urban or agricultural development. The option with the lowest proportion of highly altered landscapes is the Arrowhead-Weston/Tripoli variation, where urban and agricultural development account for only 14 percent of the total land cover. Conversely, the King-Weston option would cross the lowest proportion of natural landscapes among the study areas while the Arrowhead-Weston/Tripoli option would pass through the highest proportion of natural land cover. Combined forest, wetland, and open water land cover ranges from approximately 74 percent for the Arrowhead-Weston/Tripoli study area to 30 percent for the King-Weston/South study area.

Forested landscapes are susceptible to a wide range of impacts from transmission line corridors. (See Chapter 5.) ROWs through forests reduce the land's ability to produce forest products and increase the risk of forest fire. Linear corridors, especially those on new ROW, reduce ecological function in areas where forest fragmentation and invasion of exotic/nuisance plant species occur. ROWs are also susceptible to the impacts associated with increased ease of trespass (litter, property damage, ruttings, soil erosion, and fire).

Landscapes with a higher proportion of development are less sensitive to these types of impacts from transmission lines because most forested and wetland areas have been converted to human use. In agricultural areas, typical crop production can continue under power lines. This is not true of land where the production of forest products is prevalent. In addition, in landscapes

where a more natural environment persists, large-scale developments such as power lines have a potential to create a significantly greater adverse impact on recreational and aesthetic values.

Regardless of line location and land use, concerns about negative impacts on property values and concern about potential impacts from exposure to EMF or stray voltage are likely to be raised. For discussions on these topics see Chapter 5.

### **County forests**

County forests are public lands established by law and managed by the county for the production of forest products and to provide recreational opportunities (hiking, camping, canoeing, hunting, and fishing), wildlife habitat, watershed protection, and stream stabilization.<sup>58</sup> County forests are managed in the public interest in order to protect them from fire, insect, and disease outbreaks, and from human threats such as encroachment, over-utilization, environmental degradation, and excessive development. County forests, though managed in part for timber production, are recognized for supporting high-quality natural environments. There are 29 counties in Wisconsin that have established county forest programs. These counties are primarily in the northern half of the state. From 1994 to 1998, county forests generated \$45,895,131 of income for local units of government.

County forests support important wildlife habitat. These forests often consist of large unbroken tracts of woodland and generally exhibit a lower level of human development and disturbance than surrounding areas. This condition makes it more likely that forest interior habitats and species will be found on county forestlands than in surrounding areas. Road densities can be a useful measure of disturbance. In general, higher road densities mean greater levels of development. Lower road densities within county forest blocks would support the contention that county forests are less disturbed than the areas surrounding them. An analysis of road densities on county forestlands that lie within the study areas was conducted. The results show that the road densities within these county forestlands are significantly lower than the road densities in the study area in general. (See Table 3-11.) This is especially true for county forests greater than 1.2 square miles in size. From an environmental perspective, construction of transmission facilities in study areas with large blocks of county forest would be less desirable than construction in study areas where county forests occur less frequently.

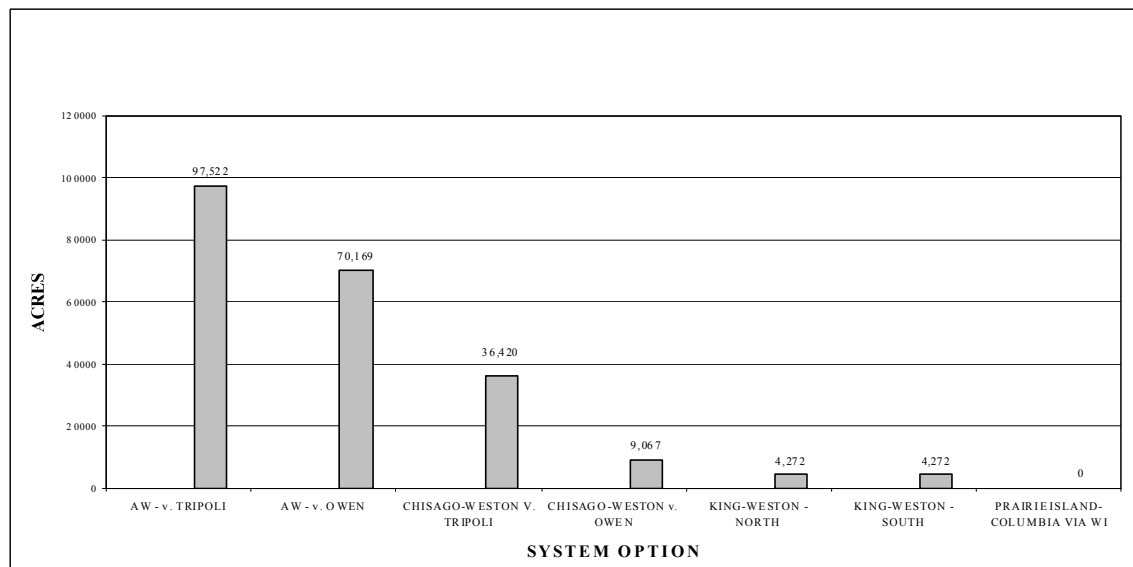
The number of acres of county forest occurring within the system option study areas ranges from 0 acres for Prairie Island-Columbia/Wisconsin to 97,522 acres for Arrowhead-Weston/Tripoli. Figure 3-9 shows the county forest acreages for each system option.

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<sup>58</sup> Wis. Stat. chapter 28.11.

Table 3-11 County forest road densities

Counties by Study Area	Road Density in County Forests (miles of roads/mi <sup>2</sup> )	Study Area Road Densities by County (miles of roads/mi <sup>2</sup> )
<b>Superior-Ladysmith</b>		
Douglas	1.25	2.18
Washburn	0.79	1.32
Sawyer	0.43	1.58
Rusk	0.00	2.19
<b>Total</b>	<b>0.96</b>	<b>1.88</b>
<b>Ladysmith-Weston/Tripoli</b>		
Rusk	0.00	1.89
Price	0.16	1.68
Lincoln	9.43	0.91
Taylor	1.16	1.23
Marathon	0.56	2.70
Oneida	0.00	3.06
<b>Total</b>	<b>0.66</b>	<b>1.99</b>
<b>Chisago-Ladysmith</b>		
Polk	8.83	2.53
Barron	0.00	2.52
Rusk	0.34	2.20
<b>Total</b>	<b>0.39</b>	<b>2.42</b>
<b>Eau Claire-Weston</b>		
Eau Claire	3.73	3.94
<b>Total</b>	<b>3.73</b>	<b>3.94</b>

**Figure 3-9 County forest acreage within system option study areas****Public lands (state-owned)**

State lands in this analysis include lands owned or leased by the state. These areas are primarily managed by the DNR and include Fisheries Management Areas (FMA), Wildlife Management Areas (WMA), state forests, state parks and trails, State Natural Areas (SNA), public boat landings, and fire tower sites.

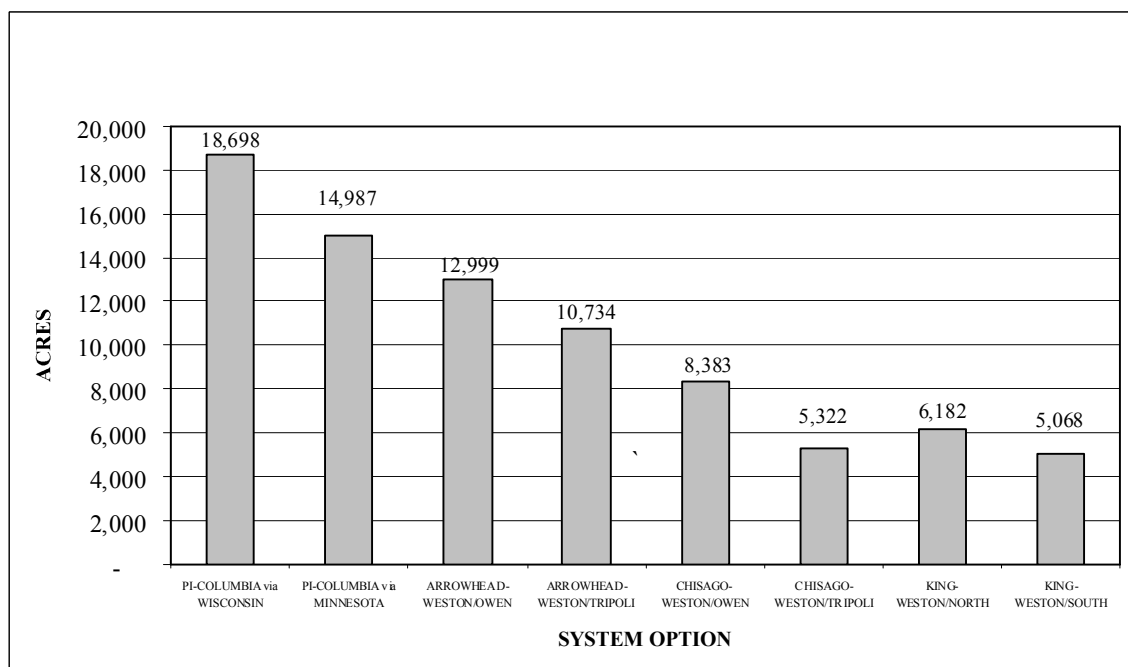
The state manages its lands for a variety of purposes. Wildlife and fisheries areas are managed primarily to provide high quality habitat for wildlife and fish. These areas support a number of human activities that focus on the use and enjoyment of natural environments, including hunting, fishing, hiking, and bird watching. These properties are typically left largely undeveloped and are free, to the greatest extent possible, of infrastructure development. Park and trail properties are more intensely managed for human recreation but development is carefully controlled so as not to destroy natural and scenic settings. A high proportion of public lands within a study area is another indication of the overall quality of the natural environment. Highly disturbed or developed areas are likely to have smaller and more scattered parcels of public lands, while areas exhibiting a more natural landscape are more likely to have larger areas reserved for the enjoyment of nature.

The acres of state-owned properties found within each study area are shown in Figure 3-10.

State-owned public lands range in size from less than one acre for some public access sites (e.g. boat landings) to over 5,000 acres for the Pine Island WMA in Columbia County. The Prairie Island – Columbia/Wisconsin study area has the largest amount of state-owned properties (18,698 acres) within its boundaries. About 64 percent (11,970 acres) is in WMAs, and about 15 percent (2,738 acres) consists of parks. The King-Weston/South study area has the smallest concentration of state-owned lands at 5,068 acres. For this study area, 80 percent of the public

lands are either WMAs (2,731 acres or 54 percent) or parks (1,335 acres or 26 percent). The proportion of state-owned land within each study area is relatively small, ranging from 3 percent for the Prairie Island-Columbia/Wisconsin study area to 0.9 percent for the Chisago-Weston/Tripoli study area. The parcels of state-owned land vary greatly in size and are generally scattered throughout a study area.

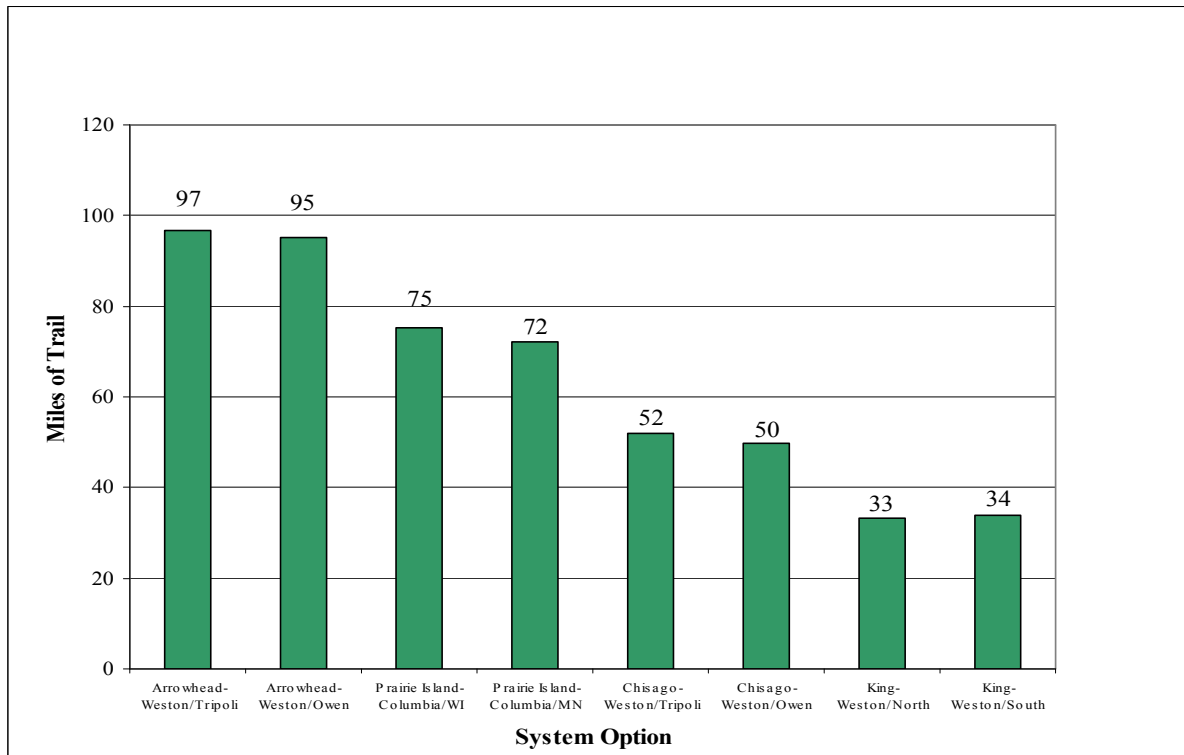
**Figure 3-10** Acres of state-owned property within study areas



### State and county trail system

An extensive system of trails has been established throughout the state. The major types of trails in Wisconsin include snowmobile, ATV, horse, hiking/nature, mountain biking, and cross-country ski trails. Trails fall under a variety of ownerships that include the state, local government, and private organizations. For this analysis only hiking, nature, and ski trails are considered because these trails are generally placed in areas where the quality of natural resource features is high. Important natural resource features for trails include scenic overlooks, interesting or important plant communities, and areas where significant opportunities to view wildlife exist. These trails are generally placed in areas where interaction with human development is limited.

The number of miles of trails within each study area was determined from the DNR trails GIS database. Only trails that are in operation or in the master planning process were included. Figure 3-11 shows the miles of trails within each system option study area. The Arrowhead-Weston study areas have the highest number of trail miles (approximately 97 miles). The King-Weston options have the lowest number of trail miles of all the options (approximately 34 miles).

**Figure 3-11 Miles of state and local trails within study option area**

### National scenic rivers, trails, and wildlife refuges

#### St. Croix National Scenic River

The National Wild and Scenic Rivers System was created under the federal Wild and Scenic Rivers Act of 1968. Congress created this system to protect selected rivers, and their immediate environments, that possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, and cultural values. These resources are to be protected for the benefit and enjoyment of present and future generations. Designation as a wild and scenic river, however, is not equivalent to a designation as a national park or wilderness area. Wild and scenic rivers are meant to exist in a “living landscape” where compatible development and use of the river are allowed. The river designation is meant to preserve the character of the river and its free-flowing nature.

The St. Croix National Scenic Riverway (NSR) is a 252-mile long corridor consisting of the St. Croix and Namekagon Rivers. This riverway was one of the original National Scenic Riverways designated under the Wild and Scenic Rivers Act. It is also designated as a unit of the national park system.

Three options (Arrowhead - Weston, Chisago-Weston, and King-Weston) each cross the St. Croix NSR.

Arrowhead-Weston would cross the St. Croix NSR at the Namekagon River in Washburn County. The Namekagon River is an important recreational resource that supports long stretches of natural habitat and is used extensively by canoeists. Three existing facility crossings are available for this option. These crossings are located within about 0.25 mile of one another and are about 8.5 miles downstream of Hayward. One crossing combines a petroleum pipeline and an overhead 161 kV transmission line (see Figure Vol. 2-21). The other crossing is at an active railroad bridge immediately downstream of the pipeline/power line crossing. A 345 kV circuit could be combined with the existing 161 kV/pipeline ROW. This stretch of the Namekagon River is generally undeveloped, but the aesthetic qualities of the river are somewhat diminished by the presence of the existing facility crossings.

Chisago-Weston would cross the St. Croix NSR near St. Croix Falls in Polk County. There are two existing facility crossings in the St. Croix Falls area. An existing power line crossing is located at the St. Croix Falls hydroelectric dam in St. Croix Falls. This area has sustained significant development on both the Minnesota and Wisconsin sides of the river. The aesthetic qualities of the St. Croix Scenic Riverway are somewhat diminished in this location, but the construction of a 345 kV line in this area would be extremely difficult because of the extensive, closely packed, residential development.

A second potential area for crossing the St. Croix River is at the Viking natural gas pipeline located about 2.5 miles south of the City of St. Croix Falls (see Figure Vol. 2-23). This existing crossing maintains a 75-foot wide cleared ROW. The river is about 600 feet wide at the crossing. This area is undeveloped and very scenic. A 345 kV crossing at this location would require a significant widening of the existing 75-foot ROW. Because there are no existing overhead crossings at this site, underground construction would most likely be needed in order to minimize the scenic impact. Construction in this area would affect both the St. Croix National Scenic Riverway and the Interstate Park.

In Commission dockets 1515-CE-102 and 4220-CE-155 (1999), the Commission approved a 345 kV underground crossing of Interstate Park and the St. Croix River as part of the Chisago-Apple River 230 kV project. If this project were ultimately built as originally approved in 1999, this crossing could be used for the Chisago-Weston system alternative<sup>59</sup>

The King - Weston option would cross the St. Croix NSR at the St. Croix River in St. Croix County. (See Figure Vol. 2-22.) There is an existing overhead power line crossing at the King Power Plant, which is located adjacent to the St. Croix River in the town of Bayport, Minnesota. The existing crossing consists of a 115/230 kV double circuit line constructed on steel lattice towers. The towers are 212 feet tall and are located on the shoreline at water level. The aesthetic values of the riverway in this area are diminished because the towers and power plant

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<sup>59</sup> The Commission's order is currently in litigation and an alternative transmission line solution is being negotiated among the affected parties. At this time, it appears that a lower-voltage transmission line (< 230 kV) may be routed across the St. Croix River near the hydroelectric dam.

can be seen from the river. A 345 kV circuit could be combined with the existing crossings in this area.

Any crossing of the St. Croix NSR could constitute a serious aesthetic impact. Such a crossing would require the active participation and cooperation of the NPS during planning and construction. A number of techniques can be employed to reduce the visual impact of any new construction. An underground crossing of the riverway would eliminate overhead wires but would still require a cleared ROW to the bank. While some site management can mitigate the visual impact of a crossing, it is a serious concern. Impacts could also be somewhat reduced by double circuiting with an existing transmission line crossing, essentially combining two ROWs into one. In general, the best option is to avoid any crossing of a scenic river if possible. For each of the system options that affect the St. Croix NSR, an existing transmission line or pipeline crossing is available for corridor sharing.

### **National Scenic Trails**

The National Trails System was established in 1968 by the National Trails System Act. There are only eight National Scenic Trails (NST), one of four categories of trail established by the Act, throughout the United States. Two trails, the Ice Age NST and the North Country NST, pass through Wisconsin. NST are established for maximum outdoor recreation potential and for the conservation and enjoyment of nationally significant scenic, historic, natural, or cultural resources of the areas through which such trails pass. The long-term goal for both the North Country NST and Ice Age NST is to establish continuous trails that are managed as premier hiking trails, nationally significant in their recreational qualities, and closed to motorized use. NST are located, to the greatest extent possible, in highly scenic rural and primitive environments. In general, crossing any NST with infrastructure corridors, such as a transmission line, should be avoided if at all possible. Choices of system options should consider first those options that limit the number of crossings, especially if the crossings are in remote areas. If a crossing cannot be avoided, efforts should be made to utilize existing road or facility crossings.

King-Weston (North and South variations) study areas do not cross any established or proposed NST. Arrowhead-Weston/Tripoli crosses a proposed segment of the North Country NST in Douglas County and established portions of the Ice Age NST in Taylor and Marathon Counties. Arrowhead-Weston/Owen crosses the proposed North Country NST in Douglas County and the Ice Age NST in Taylor County. Chisago-Weston/Tripoli and Chisago-Weston/Owen each cross the Ice Age NST three times. The Prairie Island-Columbia study area crosses an existing portion of the Ice Age NST in Columbia County. (See Figure Vol. 2-20.)

### **Upper Mississippi River National Wildlife and Fish Refuge**

The Upper Mississippi River National Wildlife and Fish Refuge was established by an Act of Congress on June 7, 1924. Land for the refuge was originally acquired through purchase, donation, and by withdrawal from the public domain. The refuge area was later enlarged by additional land acquisitions by the COE for navigational improvements.

The Upper Mississippi valley provides habitat for some 270 species of birds, 57 species of mammals, 45 species of amphibians and reptiles, and 113 species of fish. The refuge is a major

migration route for birds, both game and non-game species. Important species of birds use this refuge during migration, including the tundra swan and the canvasback duck. At times, up to 75 percent of the canvasback continental population uses the refuge, especially in the fall. Of major concern for the refuge is the potential impact to birds from collision with power lines that cross the river.

The Prairie Island-Columbia system option could cross into Wisconsin at the Mississippi River near Bay City. There is an existing 161 kV (operated at 69 kV) transmission line crossing at Bay City built with steel H-frame structures. The crossing is about 6,300 feet long and crosses the Little River (Minnesota), four islands, and several sloughs. (See Figure Vol. 2-25.)

The Prairie Island-Columbia/Minnesota system option could cross the Mississippi River at the J. P. Madgett Power plant near Alma Wisconsin. The existing crossing is a double circuit 161 kV transmission line built on steel lattice towers. The crossing is about 1,600 feet long and crosses pool 5 of the Upper Mississippi River Wildlife and Fish Refuge. Any crossing of the refuge would require the participation and cooperation of the USFWS. (See Figure Vol. 2-24.)

#### **Nationwide Rivers Inventory**

The Nationwide Rivers Inventory (NRI) was established by the NPS in partial fulfillment of Section 5(d) of the National Wild and Scenic Rivers Act (16 U.S.C. 1271-1287). This act requires all federal agencies involved in planning for the use and development of water and related land resources to consider the effect on potential national wild, scenic, and recreational rivers. The NRI is a register of river segments that meet the qualifications for being named as national wild, scenic, or recreational river areas. The original inventory was conducted by the U.S. Department of Interior with cooperation from state and local agencies in 1982. The inventory was last updated in 1994. To be listed, river segments must meet three basic criteria:

- Be free flowing and 25 miles or longer.
- Have a relatively undeveloped river and river corridor.
- Possess outstanding natural or cultural values.

Rivers included in the NRI are evaluated for scenic, recreational, geologic, fish and wildlife, historic, and cultural values. The presence of NRI river segments indicates that an area supports a high natural resource value. Figure Vol. 2-26 shows the NRI river segments in Wisconsin in relation to the system option study areas.

Table 3-12 lists NRI river segments found within each system option study area. The King-Weston study area would affect the smallest number of NRI river segments (the Wisconsin River in Marathon County). This section of the Wisconsin River would be affected by all system options except Prairie Island-Columbia. Arrowhead-Weston/Tripoli would affect the most NRI river segments of the system options analyzed, crossing six NRI Rivers.

All NRI river segments are potentially significant national resources. With the exception of the Wisconsin River, all NRI river segments affected by the various system options are valued for their scenic qualities. The scenic impact caused by a transmission line corridor is potentially significant. While certain measures can be taken to minimize the visual impacts to these valuable

river segments, the most effective method of limiting impacts is to choose an option where the potential for incurring impacts is lowest.

**Table 3-12 Rivers in the Nationwide Rivers Inventory by system option**

System Option and Study Area	NRI Listed River Segment	Resource Values
<b>Arrowhead-Weston</b>		
Superior-Ladysmith	Nemadji River	Scenic
	Totogatic River	Scenic
	Chippewa River	Scenic, recreational
	Thornapple	Scenic
Ladysmith-Weston via Tripoli	Somo River	Scenic
	Wisconsin River	Recreational, geologic
	No. Fork, Jump River	Scenic
	So. Fork, Jump River	Scenic
Ladysmith-Weston via Owen	Wisconsin River	Recreational, geologic
	Jump River	Scenic
<b>Chisago-Weston</b>		
Chisago-Ladysmith	Chippewa River	Scenic, recreational
	Thornapple River	Scenic
Ladysmith-Weston via Tripoli	Somo River	Scenic
	Wisconsin River	Recreational, geologic
	No. Fork, Jump River	Scenic
	So. Fork, Jump River	Scenic
Ladysmith-Weston via Owen	Wisconsin River	Recreational, geologic
	Jump River	Scenic
<b>King – Weston</b>		
King-Eau Claire/North	None	
King-Eau Claire/South	None	
Eau Claire-Weston	Wisconsin River	Recreational, geologic
<b>Prairie Island - Columbia</b>		
PI-Columbia-via Wisconsin	Chippewa River	Scenic, recreational
	Black River	Scenic, recreational, geologic
	La Crosse River	Scenic

#### **Outstanding and Exceptional Resource Waters**

The DNR maintains a list of outstanding and exceptional resource waters of the state. Outstanding Resource Waters (ORW) include all national and state designated wild and scenic rivers. ORW are defined as a lake or stream having excellent water quality, high recreational and aesthetic value, high quality fishing and free from point source or non-point source pollution.

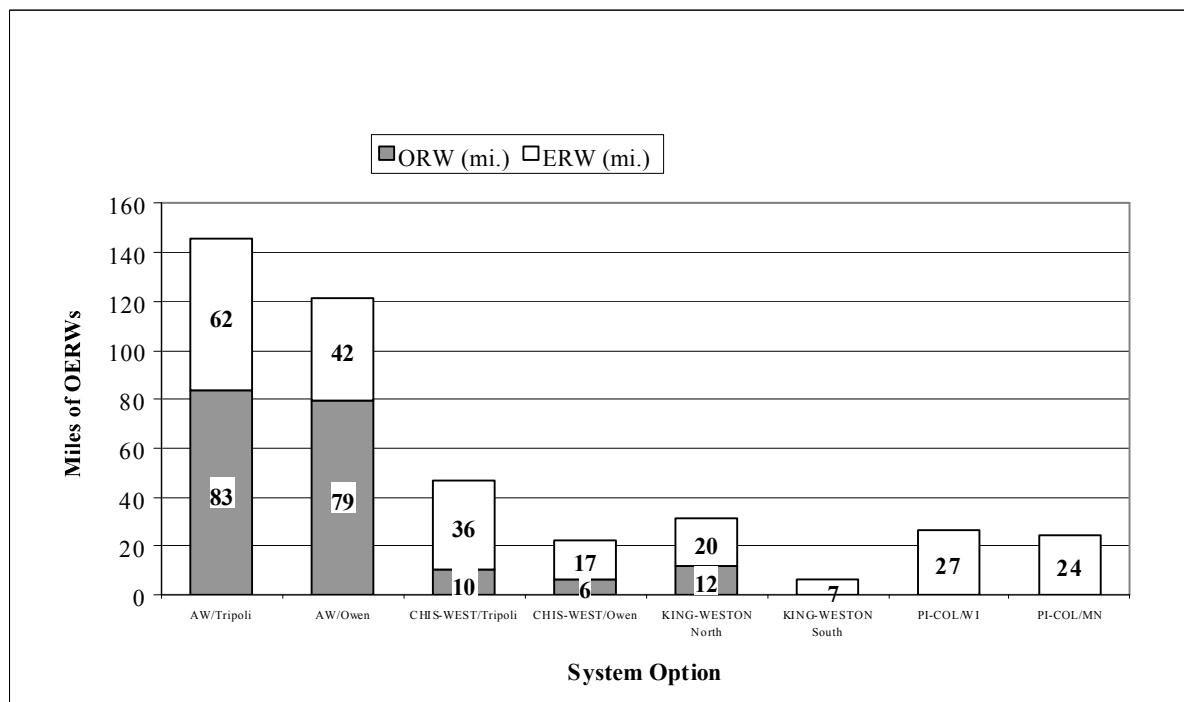
Exceptional Resource Waters (ERW) are similar to ORW in terms of water quality, recreational and aesthetic value and wildlife habitat but may be susceptible to future point source pollution.

Both Outstanding and Exceptional Resource Waters (OERW) provide unique environmental settings that have not been significantly affected by human activities. DNR field staff periodically evaluates the surface waters of the state to identify OERW. DNR experts evaluate surface waters to determine water quality, environmental significance (a measure of wildness, undisturbed shoreline, scenic quality, and presence of unique biological communities), fisheries value, and wildlife/recreational significance (including the presence of endangered, threatened, and special concern species).

A simple counting of OERW within a study area does not provide a useful measure of environmental quality because only a portion of the OERW may fall within any given study area. A better measure of the general quality of the natural environment within a study area is the overall length of OERW waters (rivers and lake shorelines) that occur within that study area. The total lengths of OERW stream/river segments and lake shorelines within each study area are shown in Figure 3-12. In a comparison between system options, study areas containing long stretches of OERW rivers and lakes suggest a relatively higher level of overall environmental quality than areas where the presence of OERW is low.

The King-Weston/South option has the fewest miles of OERW rivers/streams and lake shoreline within its study area (7 miles). Arrowhead-Weston/Tripoli has the largest amount (145 miles) of OERW streams/rivers and lake shoreline.

**Figure 3-12 Outstanding and exceptional resource waters (OERW) by system option**



### **Wisconsin Natural Heritage Inventory**

The DNR, in cooperation with the Nature Conservancy, develops and maintains an extensive database known as the Wisconsin Natural Heritage Inventory (NHI). The WNHI program focus is on locating and characterizing rare or declining species (endangered, threatened, and special concern), high quality or rare natural communities, and unique or significant natural features in Wisconsin. The NHI is continually being reviewed and updated and currently lists 134 endangered and 105 threatened species, in addition to a large number of rare and important natural communities and unique natural features. The inventory database is continually being expanded as new locations for NHI species and communities are discovered. The NHI is part of an international network of Heritage Programs.

Because of the scale of the system level review, an analysis of all locations of individual endangered, threatened and special concern species was not practical. The reason for this is two-fold. First, the number of individual locations of species within a study area is likely to be very high. Because species respond differently to power line impacts and changes in habitat, species-specific data would be too difficult to interpret within and across study areas. Secondly, the survey intensity for individual species locations has not been consistent across the state. A high number of species occurrences in an area could be caused by the fact that the area had been intensively surveyed. This makes relative comparisons between study areas susceptible to sampling bias.

In an attempt to limit sampling bias, the system analysis focuses only on the occurrence of high quality natural communities identified in the NHI. The locations of natural communities in Wisconsin were identified in the 1970s through a comprehensive statewide inventory. This inventory is being systematically updated. This difference in the way natural community occurrences have been identified means that sampling bias may be less of a problem. However, surveys for high quality natural communities have not been conducted with exact consistency across the state. The southern part of the state, the Lake Superior coastal area, and several large publicly owned properties (e.g. the Brule State Forest) have been more intensively surveyed than the state as a whole. This would suggest that a study area in the southern part of Wisconsin or one that included an area where more intense surveys have been conducted could show a disproportionately larger number of important natural communities, in part because of a more intense sampling effort.

An important measure of the environmental value for a natural community is its relative quality. NHI communities are ranked in terms of the overall quality of the site. Factors such as ecological condition and viability relative to other occurrences of the same community type are evaluated in the NHI. Natural communities are ranked as being excellent, good, marginal, or poor. The system analysis looks at the number of occurrences and the proportion of excellent and good quality NHI natural communities within each 5-mile wide study area. A relatively high number of excellent and good quality natural communities indicates a relatively high overall quality for the landscape within the study area.

Table 3-13 lists the number of NHI natural communities by study area. Of all study areas reviewed, Prairie Island-Columbia/Wisconsin has the highest concentration of known natural

communities ranked as excellent or good quality. The lowest concentration is found in the King-Eau Claire/ South option. The Prairie Island-Columbia study area has an unusually high number of quality natural communities throughout its length, although the highest concentration lies between La Crosse and the Columbia Power Plant.

**Table 3-13 Natural communities listed in the Natural Heritage Inventory**

	Number of Natural Communities by Quality Ranking				
	Excellent	Good	Marginal	Poor	Total - High Quality (Excellent & Good)
<b>Prairie Island -Columbia</b>					
Prairie Island-Columbia/Wisconsin	62	91	52	0	153
<b>Total</b>	<b>62</b>	<b>91</b>	<b>52</b>	<b>0</b>	<b>153</b>
<b>Arrowhead-Weston/Tripoli</b>					
Superior-Ladysmith	8	8	3	0	16
Ladysmith-Weston/Tripoli	6	7	4	0	13
<b>Total</b>	<b>14</b>	<b>15</b>	<b>7</b>	<b>0</b>	<b>29</b>
<b>Arrowhead-Weston/Owen</b>					
Superior-Ladysmith	8	8	3	0	19
Ladysmith-Weston/Owen	2	3	2	0	7
<b>Total</b>	<b>10</b>	<b>11</b>	<b>5</b>	<b>0</b>	<b>26</b>
<b>Chisago-Weston/Tripoli</b>					
Chisago-Ladysmith	7	3	7	0	10
Ladysmith-Weston/Tripoli	6	7	4	0	13
<b>Total</b>	<b>13</b>	<b>10</b>	<b>11</b>	<b>0</b>	<b>23</b>
<b>Chisago-Weston/Owen</b>					
Chisago-Ladysmith	7	3	7	0	10
Ladysmith-Weston/Owen	2	3	2	0	5
<b>Total</b>	<b>9</b>	<b>6</b>	<b>9</b>	<b>0</b>	<b>15</b>
<b>King-Weston/North</b>					
King-Eau Claire/North	0	13	7	0	13
Eau Claire-Weston	4	5	3	0	9
<b>Total</b>	<b>4</b>	<b>18</b>	<b>10</b>	<b>0</b>	<b>22</b>
<b>King-Weston/South</b>					
King-Eau Claire/South	2	14	8	0	16
Eau Claire-Weston	4	5	3	0	9
<b>Total</b>	<b>6</b>	<b>19</b>	<b>11</b>	<b>0</b>	<b>25</b>

### **Road densities**

Road densities can be used as an indication of the level of human development and disturbance on the landscape. Undeveloped, natural landscapes in the Midwest tend to have low road densities. For example, most county forestlands have very little human development within their boundaries. These same county forestlands tend to have very low road densities, especially when they cover an area of 1.2 square miles or greater. Areas with greater human populations tend to have a more densely designed road system and a higher level of development.

Figure 3-13 shows the average road densities for each study area. The highest road densities are found in the King-Weston/South option study area. These road densities indicate a relatively higher level of human development and disturbance when compared to other study areas. A comparison of land use within study areas is consistent with this conclusion and shows that the King-Weston options have a higher proportion of urban and agricultural land use than other system options. (See Land Cover Analysis discussed earlier in this chapter.)

The lowest overall road densities are found in the Arrowhead-Weston/Tripoli option study area. These road densities indicate a relatively lower level of human disturbance and development when compared to the study area option with the highest road densities.

The lowest road densities are found in the portions of the study areas passing through Washburn (1.32 mi/mi<sup>2</sup>), Sawyer (1.57 mi/mi<sup>2</sup>), Lincoln (0.91 mi/mi<sup>2</sup>), Price (1.68 mi/mi<sup>2</sup>) and Taylor (1.23 mi/mi<sup>2</sup>) counties. The Arrowhead-Weston/Tripoli option is the only system option that passes through all of these counties.

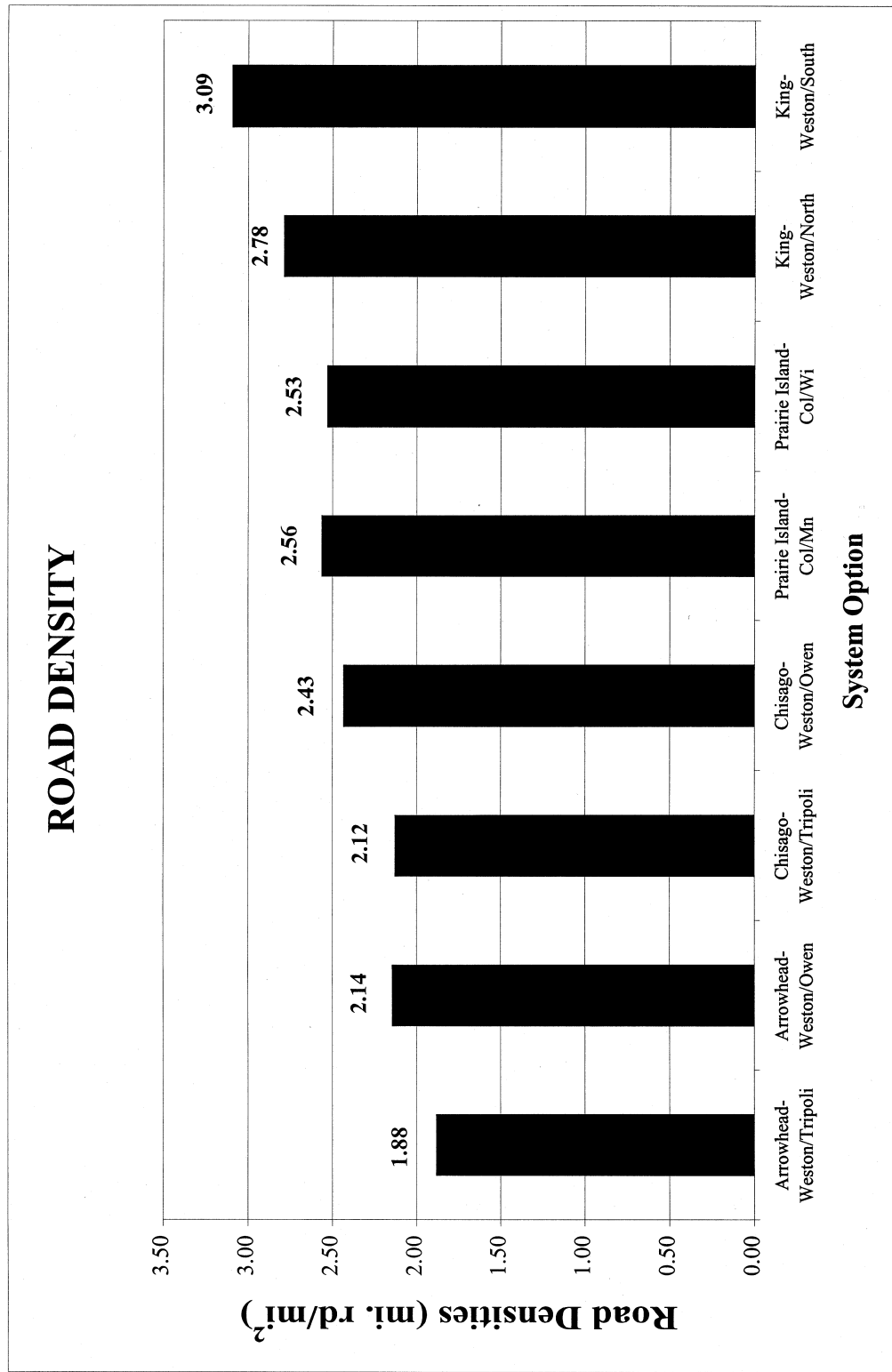
### **Human population density**

Human population densities can also be used to gauge the level of human-caused disturbance to the environment. In Wisconsin, higher population densities generally indicate urban, suburban, or agricultural landscapes where the effects of human disturbance are generally more severe than in areas where population densities are lower. As human population densities increase, the local need for goods and services and the infrastructure to support them also increases (e.g. roads, power lines). Dense human populations provide a market for commercial enterprises and lead to significant changes in land use. Densely populated areas also tend to contribute significantly more to the need for electricity than sparsely populated rural areas. From a natural resource perspective and in terms of compatibility with existing land use, transmission facilities are likely to have fewer adverse effects in an altered/developed landscape than a landscape where human development is less significant.

Building transmission facilities in areas where human population densities are higher is not without problems. Many people oppose transmission lines on or near their property for reasons such as aesthetics, concern that property values will decrease, and fear that the lines pose a health hazard because of EMF exposure or stray voltage.

A population density analysis for each study area was conducted using the 1990 U. S. Census Bureau's census block group data. A census block is a geographic area bounded on all sides by some geographic feature. A block is the smallest geographic entity for which the Census Bureau collects and tabulates census information. Figure Vol. 2-27 shows the population densities for each census block group that falls within a system option study area. Each block group is coded by color to show the approximate population density in that area. The color scheme ranges from a very light yellow to red and finally black. Darker colors indicate census blocks with higher population densities. The lowest human population densities occur in the Arrowhead-Weston study areas. The system options with the highest population densities overall are King-Weston and Prairie Island-Columbia.

Because the 1990 census data is ten years old, 1999 estimated county population densities for the 24 counties affected by one or more of the proposed study areas were also reviewed. The median population density for the 24 counties is 39.6 people/mi<sup>2</sup>. Counties where the population density is greater than the median include Marathon, Polk, Barron, St. Croix, Dunn, Chippewa, Eau Claire, Pierce, Trempeleau, LaCrosse, Monroe, Sauk, and Columbia. Five of the six counties affected by the King-Weston options and six of nine counties affected by the Prairie Island-Columbia option have population densities greater than the group median. The Arrowhead-Weston/Tripoli study area has the lowest population densities, with only one out of eight counties affected having a population density greater than the median. Arrowhead-Weston/Owen also has low population densities, with one out of seven counties affected having a population density greater than the median. Thus, the trend in population densities shown in Figure Vol. 2-27 has not changed over the past ten years.

Figure 3-13 System options – road density (miles of road/mi<sup>2</sup>)

## **Agricultural**

Wisconsin's landscape produces a wide variety of agricultural products. These products include not only the typical row-crops associated with common agricultural landscapes but also include forest crops. In northern Wisconsin the landscape principally consists of working forests. These lands, whether in public, private, or industrial ownership, produce a wide variety of crops for use in the production of paper, building materials, and high quality lumber. Counties where forest crop production is important include Douglas, Washburn, Sawyer, Rusk, Price, Oneida, Taylor, and Lincoln. The construction and operation of a high-voltage transmission line on new or expanded ROW would require the permanent removal of all trees. The land within the ROW could no longer be used for the production of forest crops. Study areas with a high proportion of forested lands will be most susceptible to permanent losses in forest crop production. The study area with the highest proportion of forested lands is Arrowhead-Weston/Tripoli. The study area with the lowest proportion of forested lands is King-Weston/South.

In the southern two-thirds of Wisconsin the principal land cover switches from forest to dairy and row-crop agriculture. Because much of the forest land has already been cleared to support row agriculture, large areas of permanently cleared lands will not be required for any new or expanded transmission line ROW. Farmers may continue to cultivate their land within the ROW. Only small areas of cropland are lost to cultivation at each pole location. Impacts do occur to farming operations because of the presence of poles and other structure within the ROW. Farmers must maneuver between and around transmission structures. The presence of poles and other structures in a field decrease farming efficiency, increases the likelihood for damage to farm equipment (because of the higher risk of collision with structures placed in fields), and create a source area for weed invasion. The study area with the greatest likelihood for incurring these types of impacts is King-Weston/South. The study area least likely to cause these types of impacts is Arrowhead-Weston/Tripoli.

## **Social issues**

The presence of a transmission line affects landowners in a number of ways. For example, landowner options for the use of their land within an ROW are restricted. It is also safe to assume that most landowners find transmission lines unsightly and feel that a transmission line detracts from the aesthetic qualities of their property. The combination of these factors will generally decrease the value of residential and recreational property. (See Chapter 5 Property Values.)

Restrictions on property use relate to the safety and maintenance of the power line. Landowners may continue to use the land but cannot build or plant trees that might interfere with the operation of the facility.

While it could be argued that aesthetic perceptions vary significantly among individuals, studies on aesthetic preferences have indicated that there is some commonality among people with regard to aesthetic perceptions. According to one study, three dimensions affect human preferences for certain landscapes. These dimensions include aesthetics, terrain, and degree of humanness. Respondents in the study preferred scenes with green vegetative features over dry

landscapes. Respondents also preferred scenes with greater amounts of topography (people preferred mountains and hills to flat landscapes). Finally, respondents preferred natural scenes over scenes that included human development. Ratings of preference declined as the levels of development and population density increased.<sup>60</sup> It could be argued, from the perspective of this study, that the aesthetic impact of a transmission line would be greater in a more natural and undeveloped landscape than in a landscape dominated by human development (even though the line may be visible to more people in a developed setting). Accordingly, this would suggest lesser aesthetic impact in areas with higher road and population densities and in areas where large-scale agricultural development has significantly altered the natural landscape.

While overall social impacts would likely be greater in study areas with higher human population densities, each individual landowner would suffer similar social impacts regardless of geographic location.

It may be important also to consider that the need for this project arises from a continued growth in the use of electricity, driven by increasing commercial, industrial, and residential development. One perspective may be that transmission facilities brought about by unchecked human consumption of electricity should not be hidden in undeveloped or remote areas but should be placed in areas clearly visible to those who drive the need and receive the benefits of this industrial expansion.

#### **Corridor sharing**

Sharing ROW corridors with existing facilities can, to some extent, reduce many of the environmental impacts from the construction and operation of a power line. In many previous decisions, the Commission has supported corridor sharing as an acceptable method for reducing a project's environmental cost. Wis. Stat. § 196.491(3)(d)3r now requires that high-voltage transmission lines proposed to increase the transmission import capability into Wisconsin use existing ROW to the extent practicable.

Possible corridor-sharing opportunities could include existing transmission lines, railroads, petroleum and natural gas pipelines, and roadways. The benefits of corridor sharing, however, are variable. Under the best circumstances, a transmission line built on an existing transmission line corridor as a double circuit line would add no additional long-term impacts to the environment. It is often necessary, however, for an existing ROW to be expanded to accommodate double circuit construction. For long high-voltage lines, the opportunities to double circuit may be limited by engineering and cost considerations, and significant new ROW may be required.

In the case of sharing corridors with roads, pipelines, and railroads, the existing ROW must always be expanded. Pipeline and railroad companies may allow some ROW sharing on the edge of the existing corridor, but significant corridor overlap can be problematic. Siting new

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<sup>60</sup> Priestley, T. 1992. Perceived Impacts of Electric Transmission Facilities – A Review of Survey-Based Studies. Edison Electric Institute.

lines adjacent to roads can be advantageous because, in addition to limiting the amount of new ROW needed, the roadbed can often support heavy equipment during construction. It is also likely, however, that a line adjacent to a road would be in closer proximity to more homes. (See Chapter 5 for more detail on the advantages and disadvantages of different types of corridor sharing.) Finally, even though corridor sharing may reduce the need for additional ROW acquisition and clearing, construction impacts associated with a large power line can still be significant, especially in areas where large wetlands are numerous and concrete foundations may be required.

For this analysis, an estimate of potential corridor sharing opportunities could be useful if significant differences can be identified between system options. Table 3-14 shows the results of a corridor sharing study included in the utilities' June 1999 WRAO report.

**Table 3-14 Corridor share potential for Arrowhead-Weston system analysis**

System Option Study Area	Corridor Sharing Opportunities	Approx. Percent Available for Sharing
<b>Prairie Island-Columbia via Wisconsin</b>		
Prairie Island -La Crosse	State Hwys-61, 35, 14, 53; Burlington Northern Railroad; Chicago and Northwestern Railroad; Chicago-Milwaukee-St. Paul and Pacific Railroad; existing transmission lines	80
La Crosse- Columbia	Chicago-Milwaukee-St. Paul and Pacific Railroad; Soo Line Railroad; Chicago and Northwestern Railroad; Interstate 90/94, 90; pipeline; existing transmission line	20
<b>Prairie Island-Columbia via Minnesota</b>		
Prairie Island- La Crosse	State Hwys-61, 35, 14, 53; Burlington Northern Railroad; Chicago and Northwestern Railroad; Chicago-Milwaukee-St. Paul and Pacific Railroad; existing transmission lines	70
La Crosse- Columbia	Chicago-Milwaukee-St. Paul and Pacific Railroad; Soo Line Railroad; Chicago and Northwestern Railroad; Interstate 90/94, 90; pipeline; existing transmission line	20
<b>Arrowhead-Weston via Tripoli</b>		
Arrowhead-Ladysmith	Pipeline; existing transmission; Central Wisconsin Railroad	60
Ladysmith-Weston	Existing transmission line; state highway transportation corridor	50
<b>Arrowhead-Weston via Owen</b>		
Arrowhead-Ladysmith	Pipeline; existing transmission; Central Wisconsin Railroad	60
Ladysmith-Weston	Existing transmission line; state highway transportation corridor; pipeline; railroad	50
<b>Chisago-Weston via Tripoli</b>		
Chisago-Ladysmith	Soo Line Railroad; State Highway 8 & 46; existing transmission line	40

System Option Study Area	Corridor Sharing Opportunities	Approx. Percent Available for Sharing
Ladysmith-Weston	Existing transmission line; state highway transportation corridor	50
<b>Chisago-Weston via Owen</b>		
Chisago-Ladysmith	Soo Line Railroad; State Highway 8 & 46; existing transmission line	40
Ladysmith-Weston	Existing transmission line; state highway transportation corridor; pipeline; railroad	50
<b>King-Weston/North</b>		
King-Eau Claire/North	Existing transmission (including 115kV, 161kV, & 345kV)	10
Eau Claire-Weston	State Hwy 29; pipeline; Soo Line Railroad; existing transmission line	95
<b>King-Weston/South</b>		
King-Eau Claire/South	Interstate 94; Chicago and Northwestern Railroad; existing transmission lines	100
Eau Claire-Weston	State Hwy 29; pipeline; Soo Line Railroad; existing transmission line	95

Source: June 1999 WRAO/WIRE Report.

The corridor sharing information in the WRAO/WIRE report is a rough estimate of potential corridor sharing opportunities. Table 3-14 shows that all system options under review have some potential for sharing corridors. In most cases there are multiple corridors available. King-Weston/South appears to have the greatest potential of all the system options considered.

Any conclusions on corridor sharing drawn from the WRAO report, however, are subject to an important caveat. The report assumes that pipeline and railroad companies will share their corridors with a transmission line. This has not been the case in recent experience. For the Arrowhead-Weston Transmission Project that is reviewed in this EIS, for example, the gas pipeline and railroad companies that own ROW in the study areas have stated that they prefer that the transmission line ROW would not overlap the ROW of their facilities.

#### **Forest fragmentation**

For a general discussion of forest fragmentation and its ecological significance, refer to the section titled Forest Resources in Chapter 5. The potential for causing forest fragmentation depends, in part, on how much forestland any proposed transmission line passes through. It is also important to consider the kinds of forests and the likelihood that a proposed line might encounter relatively large (>200 acres), unbroken forest tracts.

The relative potential of creating forest fragmentation for each system option can be estimated by combining the results of the land cover, county forest, and road density analyses. A study area dominated by forest cover would be a likely candidate for risk of fragmentation impact. A high proportion of county forests within a study area would indicate an even greater likelihood of fragmentation impact because most county forests consist of relatively large unbroken forest

tracts. (See County forest analysis, above.) Since road densities tend to correlate well with development and human population densities, an area where road densities are relatively low would also suggest a less fragmented landscape.

Table 3-15 lists the system options under review and the results from the system analyses for land cover, county forests, and road densities. Total forest land cover, in both public and private ownership (including both upland and lowland forests) for the system option study areas ranges from a high of 62 percent for Arrowhead-Weston/Tripoli to a low of 25 percent for the King-Weston-South option. In terms of county forests, the study areas for the Arrowhead-Weston options (particularly the Arrowhead-Weston-Tripoli option) contain the largest amount, in terms of acres, of county forest lands. The Prairie Island-Columbia options have the lowest amount of county forest lands. The Arrowhead-Weston/Tripoli study area has the lowest overall road density of the options reviewed, while the King-Weston/South option has the highest.

The Arrowhead-Weston/Tripoli study area has the highest percentage of forested land cover, the largest amount of county forest land, and the lowest road densities of all the study areas reviewed. This combination of factors indicates that the Arrowhead-Weston/Tripoli option has the greatest potential of creating forest fragmentation among the system options reviewed. The King-Weston/South option has the lowest overall forest cover, second lowest amount of county forestlands and the highest road densities. Of the options studied, King-Weston/South has the least likelihood of creating forest fragmentation.

**Table 3-15 Risk of forest fragmentation**

	Arrowhead-Weston/Tripoli	Arrowhead-Weston/Owen	Chisago-West/Tripoli	Chisago-West/Owen	King-West/North	King-West/South	PI-Columbia-via WI	PI-Columbia-via MN*
Forest cover	62%	50%	50%	35%	27%	25%	42%	40%
Acres of county forest	97,522	70,169	36,420	9,067	4,272	4,272	0	0
Road densities (mi rds/mi <sup>2</sup> )	1.88	2.14	2.12	2.43	2.78	3.09	2.53	2.56

\* Does not include Minnesota impact.

## Sensitive species

### Wisconsin wolf populations

A descriptive assessment of the natural environment can often be inferred from the presence or absence of an indicator species. An indicator species is one that exhibits a set of specific habitat or behavioral requirements that are reflected in the presence of important or unique landscape qualities. The eastern timber wolf is an ideal species for use in landscape-scale assessments. The wolf's complex social structure requires large landscape areas for its survival. Wolf packs operate as population subunits within a large population area. Packs are highly mobile and can

move between habitat patches within a much larger area.<sup>61</sup> This type of large-scale spatial behavior lends itself to landscape-scale habitat evaluations.

Timber wolves were once common in Wisconsin. However, in the late 19<sup>th</sup> and early 20<sup>th</sup> centuries, logging, land clearing, and settlement resulted in a rapid decline in the timber wolf population. By 1960, the timber wolf was considered extirpated in Wisconsin. With protection under the Endangered Species Act, wolves slowly began to move south and east into Wisconsin from northern Minnesota. Forests in northern Wisconsin, in recovery from the heavy logging pressure experienced during the early part of the century, began to provide acceptable habitat for wolves. Over time, as a result of immigration and natural reproduction, wolf numbers have significantly increased in northern Wisconsin.

Spatial analyses of wolf habitat and behavior in Wisconsin have shown that wolves avoid agricultural landscapes and favor areas with mixed deciduous/coniferous forests and forested wetlands. The best wolf habitat occurs in areas where road densities are low and interaction with humans is less common. Wolf packs are found in areas with road densities of 1.13 mile/mile<sup>2</sup> or less and human population densities of less than 3.94 individuals/mile<sup>2</sup>.<sup>62</sup> In Wisconsin, areas with the highest potential to support wolves are those that contain large, mostly contiguous habitat areas (mixed deciduous/coniferous forests and forested wetlands).<sup>63</sup> Wolf habitat can be described as areas where the effects of human development are relatively low and significant areas of largely unbroken forest habitat are found.

Figure Vol. 2-28 shows the location of wolf habitat and wolf pack territories in Wisconsin.<sup>64</sup> Significant portions of the Arrowhead-Weston/Tripoli and, to a lesser extent, Arrowhead-Weston/Owen and Chisago-Weston/Tripoli study areas are found in environments that support timber wolf habitat and pack territories. The extent of overlap between the Arrowhead-Weston/Tripoli study area and wolf habitat is another indication that the landscape within this study areas is less developed and supports a high quality natural environment.

Construction of a new transmission line in wolf pack territories could affect pack reproduction if construction takes place during the denning season. Denning usually occurs between early March and late June. Construction activities in pack territories could also have a negative impact on pack behavior and reproductive success. New ROW through wolf habitat and pack territories may increase human incursion into wolf habitat by providing easy access to remote

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<sup>61</sup> Mladenoff, D. J., T. A. Sickley, R. G. Haight, A. P. Wydeven. 1995. A Regional Landscape Analysis and Prediction of Favorable Gray Wolf Habitat in the Northern Great Lakes Region. *Conservation Biology* 9:279-294.

<sup>62</sup> Op. Cit.

<sup>63</sup> Mladenoff D. J., R. G. Haight, T. A. Sickley, A. P. Wydeven. 1997. Causes and Implications of Species Restoration in Altered Ecosystems. *BioScience* 47:1, 21-31.

<sup>64</sup> Data obtained from the DNR and the University of Wisconsin Madison – Forestry Department. Location of wolf habitat and territories are based on radio telemetry and wolf pack census counts and reflect known pack territories from 1997-1998.

areas frequented by wolves. Since wolves are known to avoid humans, the presence of new power line ROW could displace wolf territories.

## Summary

A system level environmental review should be conducted prior to moving forward with a construction proposal. It can be used to assist decision makers in determining which system option should be the focus of a construction application and review. A system analysis is not meant to determine the exact environmental impact caused by a specific transmission line. Instead, a system level environmental review is designed to evaluate the relative risk of environmental impact between geographically diverse transmission options. The focus of the review is on evaluating the landscape through which each system option passes. In this project, a 5-mile wide study area was defined for each system option. Each study area was based on a reasonable estimate of a representative centerline for a high-voltage transmission facility.

This evaluation focuses primarily on eleven factors that together provide a measure of the relative environmental quality of the landscapes contained within each system option study area. Because each factor evaluates a different measure of environmental quality, a simple number ranking for each option would not be appropriate. Table 3-16 lists each system option and a measurement for each environmental factor reviewed. Large differences in measured values for environmental factors lend more confidence to a conclusion that study areas differ significantly in terms of susceptibility to environmental damage. A higher relative risk for environmental impact would be associated with any system option that shows a consistent pattern of high ratings for the environmental factors under review. Conversely, any option that receives consistently low ratings would have a relatively lower risk of environmental impact for the factors reviewed.

The King-Weston study areas generally rank the lowest in terms of susceptibility to environmental impact. The landscapes within these study areas show evidence of significant change from a natural landscape to one dominated by human development. Both the King-Weston/North and/South options show the lowest percentage of land cover in forest and wetland. Conversely, these two study areas show the highest percentage of land cover devoted to commercial, agriculture, or residential development, making these study areas more compatible than other study areas with industrial developments such as transmission lines. The King-Weston/South study area also ranks lowest in terms of the number of acres of state properties, NST crossed, OERW, and rivers listed in the NRI. Both King-Weston study areas have the lowest environmental ranking in terms of road densities, the number of miles of state trails, and the second lowest in terms of the number of acres of county forest found within the system option study areas. They have the second lowest rank in terms of overall population density (i.e., high overall population densities). Building a transmission line in areas where human population/development is high can be difficult, because such lines will affect a greater number of landowners and is likely to generate more vigorous opposition than a line built in a remote and sparsely populated area, but is also less likely to involve significant environmental impact. The total number of potential landowners experiencing negative social impacts from construction of a line within a study area is highest for Prairie Island-Columbia and both King-

Weston options. The King-Weston options would have the lowest risk of impact to forest crop production and the highest risk of operational impacts to row-crop agriculture.

Arrowhead-Weston/Tripoli ranks highest in terms of susceptibility to environmental impact for nine of the eleven environmental factors reviewed. When compared to the other study areas, the landscape within the Arrowhead-Weston/Tripoli study area consists of significantly larger areas of forest and wetland habitats. The number of acres of county forest, miles of state trails, rivers listed in the NRI, and river and shoreline miles of OERW are significantly higher for Arrowhead-Weston/Tripoli than for any other system option study area. This option also has the lowest road and human population densities of the system options under review. This is evidence of a landscape largely dominated by natural landscape features, especially when compared to other study areas. The total number of potential landowners affected in this study area is likely to be the lowest of all the study areas.

All system options include some potential for corridor sharing. As a general rule, corridor sharing is most effective in reducing environmental impact when the area does not support a high quality natural landscape.

The relative risk of creating forest fragmentation impacts was derived from a comparison of the results of each study option's land cover, county forest, and road density analyses. From this analysis, the Arrowhead-Weston/Tripoli option has the highest risk of creating forest fragmentation while the King-Weston/North and South options have the lowest risk.

Wolves prefer remote areas supporting relatively undisturbed mixed forest and lowland forest habitats. Low road and human population densities also characterize wolf habitat. The presence of wolves indicates a relatively high quality natural environment where permanent impacts from human development have not occurred to any great extent. The Arrowhead-Weston and Chisago-Weston options pass through areas known to support wolf packs.

Table 3-16 Transmission line system alternatives – environmental summary

	Arrowhead- Weston/Tripoli	Arrowhead- Weston/Owen	Chisago- Weston/Tripoli	Chisago- Weston/Owen	King- Weston/North	King- Weston/South	Prairie Island- Columbia/WI	Prairie Island- Columbia/MN *
<b>ENV. FACTOR</b>								
Land Cover (% forest & wetland cover)	72%	61%	58%	43%	31%	28%	48%	48%
County Forests (acres)	97,522	70,169	36,420	9,067	4,272	4,272	0	0
State Properties (acres)	10,734	12,999	5,322	8,383	6,182	5,068	18,698	14,987
State Trails (miles)	97	96	52	51	33	34	75	72
National Scenic Trails	3	2	3	3	0	0	1	1
National Scenic Riverways	1	1	1	1	1	1	0	0
Nationwide Rivers Inventory (NRI)	8	6	6	4	1	1	3	3
OERWS (river & shoreline miles)	145	121	47	23	32	7	27	24
NHI Communities (excellent and good quality)	29	21	23	15	22	25	153	147
Road Densities (miles rd/mi <sup>2</sup> )	1.88	2.14	2.12	2.43	2.78	3.09	2.53	2.56**
Population Densities (# of high density counties in study area)	1	1	3	3	5	5	6	5
* includes only Wisconsin numbers								
** includes Minnesota Roads								

## Environmental Effects Related to Generation Sources Outside of Wisconsin

Much interest has been expressed in examining the environmental effects of increased generation outside of Wisconsin that could be expected to occur as a result of construction of a major EHV line connecting Wisconsin to western states. Interested parties have expressed concerns that the proposed Arrowhead-Weston Transmission Project would cause significant harm to the environment by contributing to air pollution and resulting in further degradation of tribal lands. These potential indirect or secondary environmental impacts would result from increases in generation or changes in generation patterns attributable to an EHV transmission line proposed by the applicants.

Potential generation sources identified for power imports from the west and north include coal-fired plants in the western U.S. and major hydroelectric facilities in Manitoba, Canada. Commission staff's analysis discussed earlier in this chapter indicates that the MAPP Canadian region would have about 1,600 to 2,000 MW of projected surplus electric power capacity during summer months with little surplus capacity available during the winter. Conversely, the analysis of the MAPP U.S. region shows that surplus capacity is very limited during the summer, but that more than 3,500 MW of surplus capacity (above and beyond 15 percent reserves) is expected to be available during non-summer months. These analyses indicate that the potential for power imports from these regions exists.

It is very difficult to complete an assessment of the potential emissions from western U.S. coal facilities without information regarding potential changes in generation patterns. Table 3-17 below, from the WIRE study, is one estimate of how much of the time power transfers from the west and south into WUMS might be expected.

**Table 3-17      Percent of time at transfer condition**

South Import Schedule	West Import Schedule			
		0	1,000 MW	2,000 MW
2,000 MW		0%	5%	N/A
1,000 MW		0%	10%	5%
0		35%	40%	5%
-1,000 MW		N/A	N/A	0%
-2,000 MW		N/A	N/A	0%

While this table indicates that 35 percent of the time no power imports from the west (or south) occur, imports of 1,000 MW or more would occur 65 percent of the time.<sup>65</sup> While the possible

<sup>65</sup> Without significant transmission system reinforcement, import levels as high as 3,000 MW would not be possible and import patterns would differ from that shown in Table 3-17. For example, in preparation for summer 2000, WUMS utilities arranged for 620 MW of capacity from the west and 540 MW of capacity from the south to meet their reserve margin requirements. (Data from June 2,000 Strategic Energy Assessment Draft Report, p. 27.)

sources of these imports have not been identified, the amount of surplus capacity available in the U.S. MAPP region for many months of the year indicates that western coal plants are a likely source.

Because the prevailing winds are from the west, it is possible that some increment of SO<sub>2</sub>, NO<sub>x</sub> particulates, and mercury emissions from western coal plants could affect Wisconsin if the proposed transmission results in a pattern of increased generation at those facilities. Also, additional CO<sub>2</sub> would be released into the atmosphere, potentially contributing to global warming. The harmful effects of mercury deposition in Wisconsin water bodies have been well documented.

In Manitoba, construction and operation of massive dams and creation of large reservoirs for purposes of using hydropower to generate electricity have flooded and made inaccessible thousands of square miles of northern forests, lakes, rivers, and muskegs that are the native lands and social fabric of the Cree Nation. It is unknown whether any changes in operation of the dams or additional construction that would cause further impacts to these lands would occur if the Arrowhead-Weston Transmission Project is approved and built.

It should also be noted that these environmental effects would not be limited to approval of the proposed Arrowhead-Weston Transmission Project but would likely be similar with respect to development of any new transmission lines that would facilitate power transfers from the west and north into and across Wisconsin.

Wisconsin statutes require the Commission to consider the environmental impacts of a project, regardless of where they would occur. However, mitigation of such effects by any means other than rejecting the proposed project is outside of the Commission's jurisdiction.